Essays on Economic Growth, Public Expenditure and Telecommunication Infrastructure

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I certify that all material in this thesis which is not my own work has been identified and that no material has previously been submitted and approved for the award of a degree by this or any other University.

Signature: ……..

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ABSTRACT

This thesis consists of four studies, presented in three main essays, empirically linking economic growth to public expenditure and telecommunication infrastructure using four different sample groups of countries with data from 1972-2012.

In the second chapter, in Study 1, the permanent growth effects of fiscal policy are investigated across countries with different income levels using the public-policy endogenous growth model, where public spending is classified by function. The endogeneity problems associated with taxes and investment are taken into account, as is a possible non-linear relationship between government expenditure and economic growth. The results have shown that gross capital formation is the only control variable that has a significant positive coefficient in all growth regressions, while the evidence of conditional convergence hypothesis is reaffirmed. An increase in transportation and communication spending is conducive to growth in both developing and high-income countries, whereas other types of spending are not.

In the third chapter, in Study 2, we firstly consider the relationship between public spending and growth with a government budget constraint. The evidence for productive expenditure being conducive to growth only exists in high-income OECD countries. Distortionary taxes are shown to have growth-deteriorating effects in both the developing country and the high-income OECD country groups.

When considering the relationship between public spending and long-run GDP per capita level in Study 3, it was found that an increase in total spending financed by non-distortionary taxes enhances the per capita level of GDP in high-income OECD countries. Regardless of implicit financing elements, increases in total spending in developing countries cannot promote long-run increases in GDP per capita levels. In developing countries, increases in the shares of health care and general public services in spending can improve long-run GDP per capita. In high-income OECD countries, increasing in the share of education in spending is conducive to increasing per capita GDP in the long-run.

In the fourth chapter, in Study 4, we assess the link between telecommunication infrastructure and economic development. The system of equations is used while considering stationarity and cointegration of variables in the models. The output dividend of fixed telephones in the period from 1975 to 1990 for the group of high-income OECD countries is higher than for developing countries.

When considering mobile phone infrastructure, an increase in penetration has positive effects on aggregate output in developing countries for the period from 1990 to 2012. There is only weak evidence that increased mobile phone penetration in high-income OECD countries has a negative effect. When fixed telephone penetration is low, an increase in mobile phone penetration enhances aggregate output. When fixed telephone penetration is already high, an increase in mobile phone penetration might have deteriorating effects. The results have shown that mobile phone and fixed telephone infrastructures are, in fact, substitutes for one another rather than complements.

Contents

List of Figures

Chapter 2

Chapter 3

Chapter 4

List of Tables

Chapter 1

Chapter 2

Chapter 3

Chapter 4

Introduction to the thesis

Introduction

Due to the fact that unequal long-term economic growth rates lead to differing levels of economic development across countries, many studies have attempted to identify the sources of growth empirically, both on the demand and the supply sides. The number of factors related to economic growth is extensive; however, this study focusses on two main sources, namely public expenditure and telecommunication infrastructure.

Firstly, we are interested in the role played by governments in the growth process and, specifically, how this affects public spending. Fiscal policy is one of the factors determining the economic growth rate in endogenous growth models (Easterly & Rebelo, 1993). Governments must provide national security and essential public goods. These public services can enhance private investment, reduce the cost of production and raise productivity. As a result, economic growth can be highly affected by changes in fiscal policy. This is different from the Solow (1956) growth model, for which fiscal policy can only determine the level of output.

Reviewing empirical literature linking fiscal policies and economic growth often produces conflicting results. Using full samples of both developed and developing countries, Lin (1994) found a positive relationship between economic growth and share of government consumption spending in GDP, whereas the results of Landau (1983) showed a negative relationship between this pair of variables. Bose et al. (2007) have provided two explanations for this disparity. The first explanation is the difference in the set of control variables. This may also include other variations in the period of study, the countries included in the data set, and the choice of econometric method. The second explanation relates to exclusion of the government budget constraint. Kneller et al. (1999) carefully take the government budget constraint into account by using implicit financing elements. These elements include non-distortionary taxes and non-productive expenditures. Without this consideration, there would be a bias in the estimates of the effect of fiscal policies on economic growth.

In this thesis, we first investigate the permanent growth effects of fiscal policy changes in the endogenous growth model using public expenditure at a disaggregated level, taking the concerns proposed by Bose et al (2007) into account. We also take the government budget constraint into account when considering the broad categories of fiscal variables within the framework proposed by Kneller et al. (1999).

Gemmell et al. (2016) argue that public-policy endogenous growth models such as those in Devarajan et al. (1996), Bose et al. (2007) and Kneller et al. (1999) do not allow for Solow-type transitional dynamics with possible persistent effects of fiscal policy. In order to consider these effects, an autoregressive distributed lag model, parameterised in error correction form is then used. We can then separately identify the short-run dynamics and the long-run equilibrium relationships between level of GDP and fiscal variables.

Secondly, telecommunication infrastructure is linked with aggregate output. It is widely accepted that infrastructure is another important source of economic development, since better communication improves efficiency when running businesses and increases firms' profitability. The adoption of telecommunication services not only brings general infrastructure benefits but is also likely to bring increasing returns from positive network externalities and spillover effects. The returns from telecommunication services could be higher than from other types of infrastructure.

Roller and Waverman (2001) pointed out that an empirical study of the relationship between telecommunication infrastructure and economic growth is subject to the problems of reverse causality and spurious correlation. In their study, the problem of simultaneity bias was controlled using a simultaneous model for telecommunication investments and economic growth. Demand and supply equations for telecommunication were specified so that telecommunication investment could be endogenised. These equations were estimated alongside an aggregate production function. As pointed out by Gruber and Koutroumpis (2011), the problem of reverse causality might be also dealt in some studies by using instrumental variables estimation. The second problem of spurious correlation was controlled by including country-specific fixed effects.

In our study, Roller and Waverman's (2001) framework is applied specifically to fixed telephone infrastructures in both developing countries and high-income OECD countries. A similar structure is also used for our estimates of mobile phone infrastructure, following the example of Gruber and Koutroumpis (2011).

Research questions

This thesis attempts to address two main questions.

Firstly, we investigate the link between public expenditure and economic growth for groups of countries with different levels of income. Several issues have been addressed by each framework.

1.) The disaggregated analysis of public expenditure and economic growth identifies permanent effects of different functions of government spending on economic growth.
2.) The relationship between broad categories of fiscal variables and economic growth is analysed with a government budget constraint, so as to identify the different growth impacts of various implicit financing elements.
3.) The relationship between public spending and long-run GDP per capita level is investigated by allowing for Solow-type transitional dynamics.

Secondly, we compare the aggregate output contribution of telecommunication infrastructure for groups of countries with different levels of income, namely developing countries and high-income OECD countries. We investigate two types of telecommunication infrastructure.

1.) The impacts of fixed telephone infrastructure on economic growth are assessed for the period between 1975 and 1990.
2.) The relationship between mobile phone infrastructure and economic growth is evaluated for the period of 1990 to 2012. The samples are classified according to both income level and level of fixed telephone penetration.

Outline of the thesis

This thesis consists of four chapters with four studies (Study 1, Study 2, Study 3 and Study 4) empirically investigating sources of growth from public spending and telecommunication infrastructure.

The first chapter summarises previous empirical and theoretical studies on public expenditure and economic growth. This is the basis for the analysis of the second chapter (Study 1) and the first part of the third chapter (Study 2).

The second chapter (Study 1) focusses on a disaggregated analysis of public expenditure and economic growth in developing and high-income countries, using the public-policy endogenous growth model. In this part of the thesis, public spending is categorised by functional classification using definitions from the International Monetary Fund.

The third chapter, which includes Study 2 and Study 3, considers two different aspects of the relationship between public expenditure and economic development. The first part (Study 2) takes the role of government budget constraint into account when considering the permanent growth effects of fiscal policy. Different implicit financing elements are included in the growth regressions in order to evaluate the impacts of fiscal change on economic growth. The second part (Study 3) focusses on the relationship between public spending and the long-run level of GDP per capita, where the transitional dynamics are taken into consideration. The analysis in this part relates to different methods and more recent studies than the second chapter and the first part of the third chapter. Thus, there is another review section specifically for literature about the relationship between government expenditure and long-run GDP per capita level.

The fourth chapter, including Study 4, investigates the relationship between telecommunication infrastructure and economic development by using a simultaneous model for telecommunication investments and aggregate output. Fixed telephones and mobile telephones are analysed separately in two different time periods.

Next, we summarise the studies theoretically and empirically investigating the link between public expenditure and economic growth.

Chapter 1: Literature review on public expenditure and economic growth

Government has a role to play both in enhancing and stabilising its country's economic performance. Public expenditure is a crucial tool for undertaking these responsibilities, since it enhances the productivity of private capital. In other words, the provision of public services is required for economic growth and sustainable development. The constrained government budget might be allocated according to functional purposes suitable for different stages of economic development in any particular country. For developing countries, public infrastructure is a fundamental input, facilitating economic activities in order to essentially promote economic growth. In high-income countries, healthcare and social welfare programs are currently a substantial part of total spending as a result of commonly and intensely found problems of population ageing.

The characteristics of public utilities and infrastructure, which are similar to public goods, make them insufficiently provided for and without public investment. The under-provision of public goods might be able to offer a key explanation as to why developing countries' economic performances are so poor. This could also be a reason for significant effects on growth from spending on these types of public goods in these countries. As government expenditure tends to only increase over time, raising taxes continuously to match government revenue with expenditure is extremely vulnerable to public resistance. Since raising revenue as to match so with increasing public expenditure seems unsustainable and impermissible; it is necessary to focus on particular functions of expenditure and re-allocate the limited resources efficiently. Hence, the relationship between economic development and public expenditure should be clearly identified and fully understood in order to achieve aforementioned reasons.

There are both theoretical and empirical literature, attempting to establish the role of government in determining economic growth. We investigate both branches of studies by focussing on the empirical ones. In the next section, we

discuss how the role of fiscal policy has been linked to economic growth in theoretical framework. The empirical literature is investigated afterwards.

1.1 Government and growth: theoretical perspective

In order to understand differences in the level of economic development across countries, it is crucial to investigate factors determining growth rates in the long run. There are two main sets of growth models: namely neoclassical growth models i.e. Solow (1956); and endogenous growth models, which we should consider.

1.1.1 Endogenous and neoclassical growth models

In neoclassical growth models, there is a significant role of private investment in creating new units of physical capital as inputs for production. However, these models fail to appropriately determine long-run growth due to diminishing returns of capital (Barro & Sala-i-Martin, 2004). Long-run growth of output per capita in these models is determined solely by technological knowledge which is exogenous to the model (Glomm & Ravikumar, 1997). Without technological change, neoclassical growth models predict that the economy will converge to a steady state. If the incentives to save or invest are affected by fiscal policies, the capital-output ratio and the level of output path will be adjusted but not the slope (Gemmell et al., 2016). In other words, the model is capable in explaining why economic policy can only change the level of the long-run growth path as discussed in Agell et al. (1997). Hence, there are effects on growth rates only during the transitional period in neoclassical growth model. This also implies that growth effect from fiscal policy merely exists during the transition to the steady state (Easterly & Rebelo, 1993). These growth impacts, however, can become considerable in the case where there is a persistent role of fiscal policies.

On the contrary, endogenous growth models can deal with the problem of diminishing returns at the aggregate level by attaining broader definition of capital and allow technical progress to be endogenous (Barro & Sala-i-Martin, 2004). Under these models, investment in human and physical capital affects

the steady-state growth rates (Kneller et al., 1999). Apart from factor accumulation, another source of endogenous growth could be knowledge creation and application of new ideas (Gemmell, 2001). By these mechanisms, long-run growth can then be appropriately determined by different determinants endogenously in growth model. The disadvantage of standard endogenous growth models is that the growth rates in these models do not exhibit the convergence property. However, in the models assuming a constant saving rate, it is possible to construct an endogenous growth model that convergence behaviour holds while exhibiting transitional dynamics.

Barro and Sala-i-Martin (2004) have illustrated two examples of convergence property in endogenous growth models. The first model initiated by Jones and Manuelli (1990) retains the characteristic of constant returns to capital in the long-run. The production function in this model combines together the AK and Cobb-Douglas functions. Constant returns to scale, and positive and diminishing returns to labour and capital are exhibited in this growth model. The convergence property is derived from the inverse relationship between average product of capital and capital per worker.

The second model utilises the production function of Arrow et al. (1961) with a constant elasticity of substitution (CES) between labour and capital. It has been shown that the CES model always exhibits the convergence for two economies with exact parameters and different values of initial capital per worker. The model instead predicts conditional convergence when the parameters are different across countries.

1.1.2 Public-policy endogenous growth models

Endogenous growth models allow us to identify the effects especially of fiscal policy on long-term growth (Barro & Sala-i-Martin, 1992). There are channels through which fiscal policy could have permanent growth effects in the endogenous growth models, for example, production externalities, productivity growth, productivity differences and fiscal effects on factor accumulation, crowding-out effects, and redistribution (Gemmell, 2001). The Barro's (1990) growth model incorporates a public sector into constant-returns model of economic growth. Public services in this model is included as a productive input

of private producers with an assumption that private inputs are not close substitutes for public inputs.

Long-run output growth can then be affected by both productive government expenditure and distortionary taxation as illustrated by Romero-Avila and Strauch (2008) using Barro's (1990) model. The population of consumers was normalised to one and they both consume and produce final output according to the production function:

$$y = Ak^{1-\gamma}g^{\gamma}, \tag{1}$$

where k represents accumulated private physical capital and g is productive government expenditure entering production function directly. The government constraint is determined by:

$$g + G = \tau y + T, \tag{2}$$

where G is other public spending that is not an input of the production function, T represents lump-sum taxation and $\boldsymbol{\tau}$ is the tax rate on output which distorts the decision to invest by private entity. Consumers maximise intertemporal utility function:

$$\int_0^{\infty} e^{-\rho t}[(c^{1-\sigma} - 1)/(1-\sigma)]\, dt, \tag{3}$$

where $\boldsymbol{\rho}$ represents the rate of time preference and σ is the elasticity of intertemporal substitution of consumption. In steady state, the growth rate of output and consumption is then determined by Equation (4):

$$\frac{\dot{c}}{c} = \frac{\dot{y}}{y} = \left(\frac{1}{\sigma}\right)\{(1-\tau)(1-\gamma)A^{\frac{1}{1-\gamma}}\left(\frac{g}{y}\right)^{\frac{\gamma}{1-\gamma}} - \rho\} \tag{4}$$

The equation above is shown that productive government expenditure affects growth positively, while distortionary taxation produces negative effect on growth.

Barro and Sala-i-Martin (1992) consider three versions of Barro's (1990) model with publicly-provided private goods, publicly-provided public goods and publicly-provided goods that are subject to congestion. It was observed that optimal tax policy depends on the characteristics of the services.

There are also other studies using endogenous growth models to explain the role of tax and government expenditure in the growth process. King and Rebelo (1990) argue that policies have the potential to influence the growth rate in models with endogenous long-run growth generating a larger influence on welfare than the neoclassical model, where the growth rate is governed by the exogenous rate of technical progress.

Mendoza et al. (1997) investigate growth effects of tax policy in the endogenous growth model which is driven by human capital accumulation. They confirm Harberger's (1964) super-neutrality conjecture that in practice tax policy is an ineffective instrument to influence growth.

In a model of Jones et al. (1993) where sequence of government expenditures are endogenous to the planner's problem in a setting which government spending has direct positive effects on investment, the asymptotic tax rate on capital income is strictly positive.

Futagami et al. (1993) develop an endogenous growth model with productive public capital along with private capital similar to that of Barro (1990).

Our further empirical analyses, in Chapter 2 and Section 3.1 of Chapter 3, emphasise on the potential effects of fiscal policy on long-term growth rates under the Barro's type endogenous growth model as illustrated by Romero-Avila and Strauch (2008).

1.2 Government and growth: empirical studies

Previous empirical literature has found a link between public expenditure and economic growth. The discussion based on bi-directional association between them. Keynesian economists believe that an increase in public expenditure could improve economic growth. On the contrary, Wagner's law predicts increase in relative share of public sector to GDP as per capita income rises (Henrekson, 1993). To understand this link appropriately, different types of public spending should be investigated accordingly. Generally, specific types of

expenditure are growth-promoting, whereas others may produce a negative result on economic development (Zagler & Durnecker, 2003). However, the results from the studies on the relationship between government and growth seem to be inconsistent regarding different specifications (Bergh & Henrekson, 2011). This reflects that any conclusion on such a link is highly sensitive to choices of models.

Table 1-1: List of studies on the relationship between government and growth

Group of countries/ specific country	Authors
All countries	Landau (1983) Barro (1991) Levine & Renelt (1992) Easterly & Rebelo (1993) Barro & Lee (1994) Lin (1994) Kelly (1997) Miller & Russek (1997) Cooray (2009) Christie (2014) Asimakopoulos & Karavias (2016) Morozumi & Veiga (2016)
High-income countries	Folster & Henrekson (2001) Bergh & Karlsson (2010)
High-income OECD countries	Kneller et al. (1999) Bleaney et al. (2001) Wahab (2004)
Developing countries	Devarajan et al. (1996) Adam & Bevan (2005) Bose et al. (2007) Moreno-Dodson (2008) Bayraktar & Moreno-Dodson (2012)
Asian economies	Abdullah et al. (2009)
African countries	Ansari et al. (1997)
EU-15 countries	Romero-Avila & Strauch (2008)
G-7 countries	Hsieh & Lai (1994)
The Gulf Cooperation Council countries	Al-Faris (2002)
Ghana	Nketia-Amponsah (2009)
India	Singh & Sahni (1984)
Italy	Del Monte & Papagni (2001)
Nigeria	Nurudeen & Usman (2010) Sevitenyi (2012)
United Kingdom	Yuk (2005)
Thailand	Jiranyakul & Brahmasrene (2007)

To compare the association between this pair of variables properly; it is required to focus on one particular set of countries at least. Such studies have been widely undertaken. The examples of literature indicating the group of countries selected for this research question are given in Table 1-1. The cross-country analysis classifying countries in terms of wealth, ranges from all countries; high-income countries, namely OECD countries (Bleaney et al., 2001; Kneller et al., 1999; Wahab, 2004); G-7 countries (Hsieh & Lai, 1994); to developing countries (Adam & Bevan, 2005; Bayraktar & Moreno-Dodson, 2012; Bose et al., 2007; Devarajan et al., 1996; Moreno-Dodson, 2008). Alternatively, countries can also be classified by using geographical location, for example: Abdullah et al. (2009) focus on Asian economies, whereas Ansari et al. (1997) analyse data on African countries. Al-Faris (2002) studies the relationship between public expenditure and growth in the Gulf Cooperation Council countries. Romero-Avila and Strauch (2008) focus on 15 European countries. Some studies compare fiscal-growth effects of groups of countries with different levels of income. Individually, the relationship between this pair of variable could be verified by looking at a particular country using time series data.

All the studies listed in Table 1-1 focus on the link between growth and fiscal variables apart from Barro (1991), Levine and Renelt (1992), and Barro and Lee (1994) where many other determinants of growth are considered alongside with fiscal variables.

1.2.1 Three generations of fiscal-growth studies

Gemmell (2001) argues that previous empirical studies on the relationship between fiscal policy and economic growth are regarded as unreliable. The two main reasons for unreliability are inappropriate estimation method and failure to take the role of government budget constraint into account. He has classified this set of studies into three generations.

The first generation of these studies existed before endogenous growth models of Romer (1986) and Barro (1990). The data used in these studies is limited while employing unreliable econometric techniques. The subsequent methodological developments have revealed that at least some of the issues;

for example, endogeneity and non-linearity were not appropriately controlled for in these studies.

Table 1-2: List of studies on the relationship between government and growth by generations of studies

Generations of fiscal-growth studies	Authors
First generation	Landau (1983) Singh & Sahni (1984)
Second generation	Barro (1991) Levine & Renelt (1992) Easterly & Rebelo (1993) Barro & Lee (1994) Hsieh & Lai (1994) Lin (1994) Devarajan et al. (1996) Ansari et al. (1997) Kelly (1997) Del Monte & Papagni (2001) Folster & Henrekson (2001) Al-Faris (2002) Wahab (2004) Yuk (2005) Jiranyakul & Brahmasrene (2007) Abdullah et al. (2009) Cooray (2009) Nketiah-Amponsah (2009) Bergh & Karlsson (2010) Nurudeen & Usman (2010) Sevitenyi (2012) Christie (2014) Asimakopoulos & Karavias (2016)
Third generation	Miller & Russek (1997) Kneller et al. (1999) Bleaney et al. (2001) Adam & Bevan (2005) Bose et al. (2007) Moreno-Dodson (2008) Romero-Avila & Strauch (2008) Bayraktar & Moreno-Dodson (2012) Morozumi & Veiga (2016)

The second generation of studies have been inspired by neoclassical and/or endogenous growth models with consideration of fiscal policies. The specifications of the models in these studies did not appropriately link with theories which have inspired them. Most studies appear to ignore the importance of government budget constraint and implicit financing of public expenditure.

The third generation studies recognise the role of government budget constraint while testing for fiscal affects; however, they need not precisely apply the government budget constraint i.e. the fiscal variables omitted from

regressions in these studies may be non-neutral. The study of Miller and Russek (1997) is among the first which incorporates the government budget constraint into the growth regression.

Our analysis considers effects of fiscal policy on growth, taking into account the role of government budget constraint while omitting fiscal variables that are potentially neutral. The above Table 1-2 classifies fiscal-growth studies into three different generations.

1.2.2 Some concerns in fiscal-growth studies

Apart from the inclusion of government budget constraint, there are also several concerns that should be taken into account in studying the relationship between fiscal variables and economic growth. Dealing with concerns about endogeneity and non-linearity can lessen inconsistency and biasedness of the estimations.

1.2.2.1 Government budget constraint (GBC)

Miller and Russek (1997) argue that many studies consider a number of different fiscal variables, but they do not examine the effects of these fiscal variables in a systematic way that controls the mode of financing. They found that the method of financing government expenditure plays an important role in determining the effect of that expenditure on economic growth.

As pointed out by Kneller et al. (1999), most early studies testing public-policy endogenous growth models fail to appropriately take into account the role of government budget constraint. The estimated results of those partial studies, which focus only on one side of the budget constraint, suffer from systematic bias relating to the assumption of implicit financing elements. This effect can be considered by using Equation (5).

$$GR_{it} = \beta_{0t} + \sum_{j=1}^{k} \beta_j^I I_{j,it} + \sum_{l=1}^{m} \beta_l^M M_{l,it} + u_{it} \quad (5)$$

$$GR_{it} = \beta_{0t} + \sum_{j=1}^{k} \beta_j^I I_{j,it} + \sum_{l=1}^{m-1} \beta_l^M M_{l,it} + \beta_m^M M_{m,it} + u_{it} \quad (6)$$

where growth, GR_{it}, in country i at time t is a function of conditioning variables, $I_{j,it}$ and a vector of fiscal variables $M_{l,it}$. When all elements of the government budget are included, the identity $\sum_{l=1}^{m} M_{l,it} = 0$ could be derived. One element of M which is $M_{m,it}$ must be omitted to avoid perfect collinearity. That omitted variable is the assumed compensating element within the budget constraint. Equation (6) is transformed to

$$GR_{it} = \beta_{0t} + \sum_{j=1}^{k} \beta_j^I I_{j,it} + \sum_{l=1}^{m-1} \gamma_l^M M_{l,it} + u_{it} \qquad (7)$$

where $\gamma_l^M = \beta_l^M - \beta_m^M$ implies that γ_l^M depends on both β_l^M and β_m^M. The coefficient on each fiscal variable in Equation (7) is interpreted as the effect of a unit change in that particular variable offset by a unit change in the omitted variable. The category chosen to be omitted should be neutral, suggesting that $\beta_m^M = 0$. In the case that omitted variable is non-neutral, the estimates will be biased.

1.2.2.2 Endogeneity

In establishing the link between government spending and economic growth, fiscal and other economic variables evolve jointly over time and there might exist reverse causality between public spending and growth (Bose et al., 2007). In other words, this can be potentially seen as a simultaneity problem, since some control variables are influenced by the rate of growth and also influence the growth rate (Landau, 1983). Kneller et al. (1999) argue that the effects of business cycle and Wagner's law are the most possible sources of simultaneity in fiscal-growth regression.

Simultaneity and reverse causality are the causes of endogeneity problems that have been dealt with in several studies, for example, Lin (1994) argues that the changes in the share of government consumption spending and the gross domestic investment are both suspected of endogeneity. Bleaney et al. (2001) also referred to investment and fiscal variables as obvious candidates of potential endogeneity in growth regressions. Folster and Henrekson (2001) have raised the concern of an endogenous selection of tax policy while using

long observation periods of cross-section studies. The Durbin-Wu-Hausman test can be used to verify this suspicion.

Estimation by instrumental variables (IV) can address this endogeneity concern; however, the selection of instruments can be problematic as pointed out by Kneller et al. (1999). Different studies come up with various sets of instruments. Kneller et al. (1999) use IV estimates in first differences. Country intercepts, the lagged levels of all fiscal variables, and the level and first difference of labour force growth and initial GDP are used as their instruments. Using different regions in Italy in their study, Del Monte and Papagni (2001) deal with possible endogeneity of private investment by using one-year lag of corruption, one-year lag of public investment per corruption, two-year lag of private investment and two-year lag of public investment as instruments. Examining possible simultaneity, Folster and Henrekson (2001) use a first differences, two-stage weighted least squares regression using instruments for the tax and government variables. The first difference of the tax and public expenditure variables are instrumented by the lagged levels of taxes and public expenditure, respectively, fixed country effects, and levels and first differences of the population and initial GDP variables.

The number of instruments included in the studies of Kneller et al. (1999), Del Monte and Papagni (2001), and Folster and Henrekson (2001) could be excessive. In order to avoid the problem of instrument proliferation, Morozumi and Veiga (2016) use only one lag as an internal instrument to tackle the possible endogeneity of fiscal variables. Barro and Lee (1994) also use lagged values of explanatory variables as instruments. Romero-Avila and Strauch (2008) instrument private investment and inflation by their two lags. The instruments chosen by Bose et al. (2007) for private investment and political instability are their averages for five-years prior to the specific decade.

Hausman (1978) suggested comparing ordinary least squares (OLS) and two-stage least squares (2SLS) estimators as a formal test of endogeneity. We need to investigate whether OLS yield consistent estimates in order to use instrumental variable estimation (Davidson & MacKinnon, 1993). If residuals were not asymptotically independent of the control variables, the instrumental variable (IV) estimators would still be consistent but the OLS estimators would not be.

To test for endogeneity, the Durbin-Wu-Hausman test is based on a vector of contrasts between OLS and IV estimators. According to Davidson and MacKinnon (1993), these statistics can be computed by artificial regressions. As discussed by Baum et al. (2003), this way of using Durbin-Wu-Hausman test requires the estimation of the first-stage regression for each of the potentially endogenous variables. Then their residual series are augmented to the original model and the F-test is used to test for endogeneity.

Alternatively, the simultaneity problem might be dealt with simultaneous equations instead of using single equation. Later on, in Chapter 2, we use two-stage least squares estimation to take into account possible endogeneity in growth regression of investment and tax variables by using their one-year lag variables as instruments.

1.2.2.3 Non-linearity

There is a possibility that the relationship between public spending and growth can be non-linear. Barro (1990) has shown that growth rate increases with public spending when government is small and growth declines, if the size of government becomes large. Similarly, Devarajan et al. (1996) argue that both theory and intuition suggest that expenditure ratios and growth might have a non-linear relationship. Productive expenditures can be positively associated with growth when their shares in the budget are low but this turns negative when the share gets large. As the share keeps rising, decreasing returns to scale set in, and the relationship between the two variables turns negative.

Bayraktar and Moreno-Dodson (2012) try to capture this type of non-linearity between growth and public spending by adding additional variable to the specification. The variable added is either the squared value of total public spending or the squared term of productive public spending. Devarajan et al. (1996) add the square terms of the ratios of current and capital expenditure to total expenditure to the equations for non-linear specification.

However, including a quadratic term may fail to detect non-linearity as suggested by Christie (2014). The main reason is that the effect might be present in the forms that could not be captured by a quadratic term. In order to test Barro's non-linear hypothesis, the non-linearity of the impact of government

size on economic growth might be instead identified around the threshold level of public spending (Asimakopoulos & Karavias, 2016; Christie, 2014). Both studies have found asymmetric effects around threshold level of government spending.

Non-linearites in the functional form can be verified by using Ramsey's (1969) RESET test.

1.3 Measuring government expenditure

In order to understand the relationship between government and growth, it is important to identify the measure of government which would be considered. In general, the apparent representative for the size of government is its expenditure. The measures of government expenditure found in previous empirical studies can mainly be classified into three different groups. Firstly, government expenditure at aggregate level represents public sector as a whole. Secondly, public spending is separated into broad categories depending on various purposes or theoretical definition. Thirdly, it is classified into a disaggregated level either by function or by economic classification according to the International Monetary Fund (IMF) guidelines.

1.3.1 Aggregate level of government expenditure

There are several examples regarding the measures of aggregate level of government expenditure which are used for this analysis. The first example is aggregate government expenditure in Wahab (2004) and Abdullah et al. (2009). Similarly, Jiranyakul and Brahmasrene (2007) focus on real government expenditure. Secondly, government expenditure might be measured as a ratio of gross domestic product (GDP). This ratio is a proxy for comparing the size of government across countries with highly different level of GDP in relative terms. The share of government spending to GDP is widely used by a number of studies. Alternatively, Singh and Sahni (1984), Ansari et al. (1997) and Al-Faris (2002) use per capita public expenditure.

Furthermore, the rate of change of total government expenditure weighted by the share of government spending in GDP is analysed in Nketia-Amponsah (2009).

1.3.2 Broad categories of government expenditure

Two main criteria have been observed for a broad definition of government expenditure;

1.) Capital and recurrent expenditure

The first classification focusses on the difference between consumption spending and investment spending. They can also be called recurrent and capital expenditure. A number of studies; for example, Devarajan et al. (1996); Al-Faris (2002); Bose et al. (2007); Nurudeen and Usman (2010); Sevitenyi (2012); and Morozumi and Veiga (2016) separate government expenditure into capital and recurrent expenditure. The effects of public investment on growth are also investigated in several studies; however, it is not always necessarily included in the estimation together with public consumption in a particular study. One of the exceptions is the study by Romero-Avila and Strauch (2008) which government consumption, investment and transfer are considered together.

Instead of using the level of expenditure, Lin (1994) uses both growth rate of government consumption and government consumption spending share of GDP. Levine and Renelt (1992) also uses the growth rate of the share of government consumption.

2.) Productive and non-productive expenditure

The second criterion, which was used in Kneller et al. (1999) and Bleaney et al. (2001), classifies expenditure according to whether it is included as an argument in the private production function. Productive expenditure has a direct impact on the rate of growth

through production function, whereas non-productive expenditure does not affect the steady-state rate of growth (Kneller et al., 1999).

There is some other literature following the same convention in defining productive expenditure and non-productive expenditure (Bayraktar & Moreno-Dodson, 2012; Moreno-Dodson, 2008). Adam and Bevan (2005) and Christie (2014) focus only on productive expenditure, whereas Lin (1994) investigates the role of non-productive government consumption in determining economic growth.

There are few other definitions of government expenditure being analysed; for example, core and non-core spending (Bayraktar & Moreno-Dodson, 2012) and economic and social expenditure (Moreno-Dodson, 2008). These classifications focus on dividing types of functional spending into specific groups similar to productive and non-productive expenditure.

See Table 1-3 for the full list of studies using broad categories of government expenditure.

Table 1-3: List of broad categories used for public expenditure

Expenditure variables	Description	Authors
Capital expenditure	The ratio of capital expenditure to total expenditure	Devarajan et al. (1996)
	Capital expenditure per capita	Al-Faris (2002)
	Government capital expenditure %GDP	Bose et al. (2007)
	Government total capital expenditure	Nurudeen & Usman (2010)
	Total capital expenditure in real term	Sevitenyi (2012)
	Capital spending as a ratio to GDP	Morozumi & Veiga (2016)
Recurrent expenditure	The ratio of current expenditure to total expenditure	Devarajan et al. (1996)
	Current expenditure per capita	Al-Faris (2002)
	Current expenditure	Bose et al. (2007)
	Total recurrent expenditure	Nurudeen & Usman (2010)
	Total recurrent expenditure in real term	Sevitenyi (2012)
	Current spending as a ratio to GDP	Morozumi & Veiga (2016)
Government expenditure	The share of government spending to GDP	Hsieh & Lai (1994)
	Share of total government expenditure in GDP	Devarajan et al. (1996)

Expenditure variables	Description	Authors
	Total government expenditure to GDP	Miller & Russek (1997)
	Total government expenditure as a share of GDP	Folster & Henrekson (2001)
	The ratio of public expenditure to GDP	Al-Faris (2002)
	The ratio of government expenditure	Wahab (2004)
	Total expenditure and net lending as a share of GDP	Adam and Bevan (2005)
	Log of the share of government expenditure in GDP	Yuk (2005)
	Real government expenditure	Jiranyakul & Brahmasrene (2007)
	The ratio of total public expenditure to GDP	Moreno-Dodson (2008)
	Total expenditures as a share of GDP	Romero-Avila & Strauch (2008)
	Aggregate government expenditure	Abdullah et al. (2009)
	Government expenditure to GDP	Cooray (2009)
	The rate of change of real government expenditure weighted by the share of government expenditure in GDP	Nketiah-Amponsah (2009)
	Total public expenditure as share of GDP	Bergh & Karlsson (2010)
	The ratio of total public expenditure to GDP	Bayraktar & Moreno-Dodson (2012)
	Total government expenditure as a share of GDP	Christie (2014)
Public investment	The ratio of real public domestic investment to real GDP	Barro (1991)
	The ratio of real public domestic investment to real domestic investment	Barro (1991)
	Total public investment to GDP	Easterly & Rebelo (1993)
	Public investment to GDP	Kelly (1997)
	Share of real public investment in real GDP	Del Monte & Papagni (2001)
	Government investment as a share of GDP	Romero-Avila & Strauch (2008)
	Public investment to GDP	Cooray (2009)
Public consumption	The share of government consumption expenditure in GDP	Landau (1983)
	The ratio of real government consumption expenditure to real GDP	Barro (1991)
	Government consumption share of gross domestic product	Levine & Renelt (1992)

Expenditure variables	Description	Authors
	Growth of the share of government consumption	Levine & Renelt (1992)
	The ratio of government consumption to GDP	Easterly & Rebelo (1993)
	The average annual growth rate of consumption spending	Lin (1994)
	The average annual growth rate of consumption spending share of GDP	Lin (1994)
	The ratio of real government consumption to real GDP	Barro & Lee (1994)
	Government consumption as a share of GDP	Folster & Henrekson (2001)
	Government consumption spending as a share of GDP	Romero-Avila & Strauch (2008)
	Public consumption to GDP	Cooray (2009)
	General government final consumption as a share of output	Asimakopoulos & Karavias (2016)
Government transfers	Total transfers as a share of GDP	Romero-Avila & Strauch (2008)
Per capita public expenditure	Per capita public expenditure	Singh & Sahni (1984)
	Per capita government expenditure	Ansari et al. (1997)
	Government expenditure per capita	Al-Faris (2002)
Productive expenditure	Aggregation of general public services, defence, educational, health, housing, and transportation and communication expenditure to GDP	Kneller et al. (1999)
	Aggregation of general public services, defence, educational, health, housing, and transportation and communication expenditure to GDP	Bleaney et al. (2001)
	Aggregation of education, health, hosing, transport and communication, public order and safety, and non-interest administration expenditure to GDP	Adam & Bevan (2005)
	Aggregation of general public services, defence, educational, health, housing, and transportation and communication expenditure to GDP	Moreno-Dodson (2008)
	Aggregation of general public services, defence, educational, health, housing, and transportation and communication expenditure to GDP	Bayraktar & Moreno-Dodson (2012)
	The sum of expenditure on education, health, housing, transportation and communication relative to GDP	Christie (2014)

Expenditure variables	Description	Authors
Non-productive expenditure	Annual growth rate of government spending less education and defence spending	Lin (1994)
	Annual growth of the ratio of real government spending to real GDP less nominal ratios to GDP of education and defence spending	Lin (1994)
	Aggregation of social security and welfare, recreational, and economic services expenditure to GDP	Kneller et al. (1999)
	Aggregation of social security and welfare, recreational, and economic services expenditure to GDP	Bleaney et al. (2001)
	Aggregation of social security and welfare, recreational, and economic services expenditure to GDP	Moreno-Dodson (2008)
	Aggregation of social security and welfare, recreational, and economic services expenditure to GDP	Bayraktar & Moreno-Dodson (2012)
Other expenditure	Other expenditure (unclassified)	Kneller et al. (1999)
	Other expenditure (unclassified)	Bleaney et al. (2001)
Core spending	Expenditure on general public services, education, health, housing, transportation and communication, and fuel and energy	Bayraktar & Moreno-Dodson (2012)
Non-core spending	Expenditure on social security and welfare, recreation, agriculture, mining, and other economic affairs and services	Bayraktar & Moreno-Dodson (2012)
Economic expenditure	Expenditure on fuel and energy, agriculture, mining, transportation and communication, and other economic affairs and services	Moreno-Dodson (2008)
Social expenditure	Expenditure on education, social security and welfare, housing, and recreation	Moreno-Dodson (2008)

1.3.3 Disaggregated analysis of public expenditure

Once the database for public expenditure had been systematically developed, a disaggregated analysis of public expenditure became accessible and credible. Public expenditure is classified by function according to different activities associated with government spending. The International Monetary Fund (IMF) is the main source of a cross-country database for disaggregated data of public expenditure. The database is called “Government Finance Statistics (GFS)”. This database is the most reliable source for cross-country study. Most of cross-country studies rely on the definition described by the IMF. The public expenditure variables usually appear in growth regression as ratios of GDP.

The following Table 1-4 consists of the list of studies using specific types of public expenditure for such analysis.

Table 1-4: List of public expenditure used in disaggregated analysis

Types of expenditure	Description	Authors
Social and community services	Social and community services in real term	Sevitenyi (2012)
Administration	Expenditure on parliament, state, union territories, general administration, audit, jail, justice, police, external affairs, supplies, disposals and public sector undertakings	Singh & Sahni (1984)
	Administration in real term	Sevitenyi (2012)
Economic services	Economic affairs and services expenditure to GDP	Miller & Russek (1997)
	Economic services in real term	Sevitenyi (2012)
Transfers	Transfers in real terms	Sevitenyi (2012)
Agriculture	The ratio of agricultural investment to GDP	Easterly & Rebelo (1993)
	Government expenditure in agriculture	Nurudeen & Usman (2010)
Health	The ratio of health investment to GDP	Easterly & Rebelo (1993)
	The ratio of health to total expenditure	Devarajan et al. (1996)
	Health expenditure to GDP	Kelly (1997)
	Health expenditure to GDP	Miller & Russek (1997)
	Health expenditure to GDP	Moreno-Dodson (2008)
	Health expenditure to GDP	Cooray (2009)
	Log of government expenditure on health to GDP	Abdullah et al. (2009)
	Share of total expenditure on health	Nketia-Amponsah (2009)
	Government expenditure in health	Nurudeen & Usman (2010)
Education	Total investment in education	Landau (1983)
	The ratio of educational investment to GDP	Easterly & Rebelo (1993)
	The ratio of education to total expenditure	Devarajan et al. (1996)
	Education expenditure to GDP	Kelly (1997)
	Education expenditure to GDP	Miller & Russek (1997)
	Education expenditure and investment	Bose et al. (2007)
	Education expenditure to GDP	Moreno-Dodson (2008)

Types of expenditure	Description	Authors
	Log of government expenditure on education to GDP	Abdullah et al. (2009)
	Education expenditure to GDP	Cooray (2009)
	Share of total expenditure on education	Nketia-Amponsah (2009)
	Government expenditure on education	Nurudeen & Usman (2010)
Defence	Expenditure on defence services and capital outlays	Singh & Sahni (1984)
	The ratio of defence to total expenditure	Devarajan et al. (1996)
	Defence expenditure to GDP	Kelly (1997)
	Defence expenditure to GDP	Miller & Russek (1997)
	Defence expenditure	Bose et al. (2007)
	Log of government expenditure on defence to GDP	Abdullah et al. (2009)
	Military expenditure to GDP	Cooray (2009)
	Government expenditure on defence	Nurudeen & Usman (2010)
Transport and communication	The ratio of transportation and communication investment to GDP	Easterly & Rebelo (1993)
	The ratio of transportation and communication to total expenditure	Devarajan et al. (1996)
	Transportation and communication expenditure to GDP	Kelly (1997)
	Transportation and communication expenditure to GDP	Miller & Russek (1997)
	Transportation and communication expenditure and investment	Bose et al. (2007)
	Transportation and communication expenditure to GDP	Moreno-Dodson (2008)
	Government expenditure in transport and communication	Nurudeen & Usman (2010)
Housing	The ratio of housing and urban infrastructure investment to GDP	Easterly and Rebelo (1993)
	Housing expenditure to GDP	Kelly (1997)
Mining, manufacturing and construction	The ratio of industry and mining investment to GDP	Easterly & Rebelo (1993)
	Mining, manufacturing and construction expenditure to GDP	Kelly (1997)

Types of expenditure	Description	Authors
Social and development	Expenditure on education, medical and public health, agriculture, rural development, industries, broadcasting, community development projects, labour and employment, capital outlays for railways post and telegraph, irrigation, electrification, civil aviation and transportation	Singh & Sahni (1984)
	Social security expenditure to GDP	Kelly (1997)
	Social-security and welfare expenditure to GDP	Miller & Russek (1997)
Infrastructure	Share of total expenditure on infrastructure	Nketia-Amponsah (2009)

1.4 Conditioning variables

The other important set of variables included in the studies of the relationship between public expenditure and growth is the set of conditioning variables. It is very crucial that the criteria of selecting control variables are clearly and systematically defined. Otherwise, the results of the study will not be reliable. According to recent literature survey, the wide range of conditioning variables can be broadly classified into economic indicators, social indicators and other relevant indicators respectively. The list of conditioning variables is in Table 1-5.

Table 1-5: List of conditioning variables

Conditioning variables	Description	Authors
Economic indicators		
Lagged growth	Lagged value of per capita GDP growth	Bleaney et al. (2001)
	Lagged value of per capita GDP growth	Miller & Russek (1997)
	Lagged growth of GDP per capita	Asimakopoulos & Karavias (2016)
US GDP growth		Romero-Avila & Strauch (2008)
Initial GDP	Gross domestic product in 1960	Kelly (1997)
	GDP at the initial year of each subperiod	Bergh & Karlsson (2010)
Initial per capita GDP	1960 value of real per capita GDP	Barro (1991)
	Square of 1960 value of real per capita GDP	Barro (1991)
	Initial level of real per capita GDP in 1960	Levine & Renelt (1992)

Conditioning variables	Description	Authors
	Per capita GDP, 1960	Easterly & Rebelo (1993)
	Initial per capita GDP	Barro & Lee (1994)
	Log of real GDP per capita at the initial year	Lin (1994)
	Initial GDP per capita	Folster & Henrekson (2001)
	Log of initial GDP per capita	Bose et al. (2007)
	GDP per capita in constant 2000 USD	Moreno-Dodson (2008)
	Initial level of per capita GDP	Abdullah et al. (2009)
	Initial GDP	Cooray (2009)
	Log of initial GDP per capita (constant 2000 USD)	Christie (2014)
	Initial real GDP per capita	Morozumi & Veiga (2016)
Per capita output	Per capita real GDP	Landau (1983)
	GNP per capita	Adam & Bevan (2005)
Lagged per capita output	Lagged real per capita GDP	Miller & Russek (1997)
Investment	The ratio of real domestic investment to real GDP	Barro (1991)
	Investment share of GDP	Levine & Renelt (1992)
	The ratio of real gross domestic investment to real GDP	Barro & Lee (1994)
	Gross domestic investment as a percentage of real GDP	Lin (1994)
	The investment share of GDP	Miller & Russek (1997)
	Investment ratio	Kneller et al. (1999)
	Investment as %GDP	Bleaney et al. (2001)
	Gross investment as a share of GDP	Folster & Henrekson (2001)
	Investment as %GDP	Adam & Bevan (2005)
	Savings in physical capital	Abdullah et al. (2009)
	The ratio of investment to GDP	Nketia-Amponsah (2009)

Conditioning variables	Description	Authors
	Investment share of GDP	Bergh & Karlsson (2010)
	Investment as %GDP	Christie (2014)
	The gross capital formation as a share of output	Asimakopoulos & Karavias (2016)
Private investment	Ratio of private investment to GDP	Hsieh & Lai (1994)
	Private investment to GDP	Kelly (1997)
	Private investment	Del Monte & Papagni (2001)
	Private investment share of GDP	Bose et al. (2007)
	Private investment to GDP	Moreno-Dodson (2008)
	Private investment rate	Romero-Avila & Strauch (2008)
	Share of private investment to GDP	Cooray (2009)
	Private investment to GDP	Bayraktar & Moreno-Dodson (2012)
	Private investment share of GDP	Morozumi & Veiga (2016)
Savings	Gross private saving as a fraction of GDP	Folster & Henrekson (2001)
	Gross national saving as a fraction of GDP	Folster & Henrekson (2001)
Budget balance	The government surplus to GDP	Miller & Russek (1997)
	Government budget surplus	Kneller et al. (1999)
	Government budget surplus	Bleaney et al. (2001)
	Budget deficit %GDP	Adam & Bevan (2005)
	Government surplus/deficit	Bose et al. (2007)
	Log of budget balance	Abdullah et al. (2009)
	Overall government fiscal balance	Nurudeen & Usman (2010)
	Fiscal balance to GDP	Moreno-Dodson (2008)
	Fiscal balance to GDP	Bayraktar & Moreno-Dodson (2012)
	Overall budget deficit as a ratio to GDP	Morozumi & Veiga (2016)

Conditioning variables	Description	Authors
Revenue	Total government revenue to GDP	Miller & Russek (1997)
	Fiscal revenue to GDP	Moreno-Dodson (2008)
	Total current revenue as a share of GDP	Romero-Avila & Strauch (2008)
	Fiscal revenue to GDP	Bayraktar & Moreno-Dodson (2012)
	Total revenue as a ratio to GDP	Morozumi & Veiga (2016)
Tax revenue	Total taxes as a share of GDP	Folster & Henrekson (2001)
	Tax revenue as %GDP	Adam & Bevan (2005)
	Tax revenue %GDP	Bose et al. (2007)
	Total direct taxation as a share of GDP	Romero-Avila & Strauch (2008)
	Total indirect taxation as a share of GDP	Romero-Avila & Strauch (2008)
	Total tax revenue as a share of GDP	Bergh & Karlsson (2010)
Corporate income tax	Corporate income tax revenue to GDP	Miller & Russek (1997)
Individual income tax	Individual income tax revenue to GDP	Miller & Russek (1997)
Social security tax	Social security tax revenue to GDP	Miller & Russek (1997)
	Social security contribution as a share of GDP	Romero-Avila & Strauch (2008)
International tax	International tax revenue to GDP	Miller & Russek (1997)
Other revenue	Other tax revenue to GDP	Miller & Russek (1997)
	Taxation on international trade, non-tax revenues and other tax revenues	Kneller et al. (1999)
	Taxation on international trade, non-tax revenues and other tax revenues	Bleaney et al. (2001)
Non-tax revenue	Non-tax revenue to GDP	Miller & Russek (1997)
	Non-tax revenue %GDP	Adam & Bevan (2005)
Distortionary taxes	Taxation on income and profit, social security contributions, taxation on payroll and manpower, and taxation on property	Kneller et al. (1999)

Conditioning variables	Description	Authors
	Taxation on income and profit, social security contributions, taxation on payroll and manpower, and taxation on property	Bleaney et al. (2001)
	Log of distortionary taxes	Abdullah et al. (2009)
Non-distortionary taxation	Domestic goods and services tax revenue to GDP	Miller & Russek (1997)
	Taxation on domestic goods and services	Kneller et al. (1999)
	Taxation on domestic goods and services	Bleaney et al. (2001)
Tariff rates	Tariff rates on capital goods and intermediate products.	Barro & Lee (1994)
Tax rate	Effective labour tax rate	Romero-Avila & Strauch (2008)
	Effective capital tax rate	Romero-Avila & Strauch (2008)
	Effective consumption tax rate	Romero-Avila & Strauch (2008)
Grants	Grants as %GDP	Adam & Bevan (2005)
Seigniorage	Seigniorage %GDP	Adam & Bevan (2005)
Trade ratio	Trade share in 1970	Easterly & Rebelo (1993)
	Sum of exports and imports to GDP	Kelly (1997)
	The import plus export share of GDP	Miller & Russek (1997)
	Export plus import of goods and services as a fraction of GDP	Folster & Henrekson (2001)
	Initial trade ratio	Bose et al. (2007)
	Openness %GDP	Moreno-Dodson (2008)
	Ratio of exports plus imports to GDP	Romero-Avila & Strauch (2008)
	Exports plus imports %GDP	Christie (2014)
	Openness to trade	Asimakopoulos & Karavias (2016)
Exports	The ratio of exports to GDP	Levine & Renelt (1992)
	Growth of export share of GDP	Levine & Renelt (1992)
	Export of goods and services as a fraction of GDP	Folster & Henrekson (2001)
	Share of exports to GDP	Yuk (2005)

Conditioning variables	Description	Authors
	Rate of change of real exports	Nketia-Amponsah (2009)
Imports	Import of goods and services as a fraction of GDP	Folster & Henrekson (2001)
Growth rate of terms of trade		Barro & Lee (1994) Bose et al. (2007)
Debt Servicing	Expenditure on central and state government debt servicing The avearge growth rate of domestic credit The standard deviation of domestic credit growth Debt financing %GDP Credit %GDP	Singh & Sahni (1984) Levine & Renelt (1992) Levine & Renelt (1992) Adam & Bevan (2005) Cooray (2009)
Net lending	Lending minus repayments Lending minus repayments Net lending %GDP	Kneller et al. (1999) Bleaney et al. (2001) Adam & Bevan (2005)
Interest	Interest on debt %GDP	Adam & Bevan (2005)
Money supply	The ratio of M2 to GDP in 1970 The ratio of broad money (M2) to GDP Real money supply by broad definition (M2)	Easterly & Rebelo (1993) Bose et al. (2007) Jiranyakul & Brahmasrene (2007)
Inflation	The average inflation rate The standard deviation of inflation The GDP implicit price deflator rate of inflation Percentage change in the consumper price index Inflation rate calculated from consumer price index Inflation rate Inflation rate Inflation rate calculated from consumer price index Inflation rate	Levine & Renelt (1992) Levine & Renelt (1992) Miller & Russek (1997) Folster & Henrekson (2001) Moreno-Dodson (2008) Romero-Avila & Strauch (2008) Nurudeen & Usman (2010) Bayraktar & Moreno-Dodson (2012) Christie (2014)

Conditioning variables	Description	Authors
	Percentage change of CPI	Asimakopoulos & Karavias (2016)
Deviation of investment deflator	The magnitude of the deviation of the 1960 PPP value for the investment deflator	Barro (1991)
Shock	A weighted averages of changes in the world real interest rate, and the export price index and import price index for each country	Devarajan et al. (1996)
Social indicators		
Primary school enrolment	School enrolment rates at primary level in 1960	Barro (1991)
	Primary school enrolment in 1960	Easterly & Rebelo (1993)
Secondary school enrolment	School enrolment rates at secondary level in 1960	Barro (1991)
	Initial secondary school enrolment	Levine & Renelt (1992)
	Secondary school enrolment in 1960	Easterly & Rebelo (1993)
	Male and female secondary school enrolment ratios	Barro & Lee (1994)
	The growth rate of male and female secondary schooling.	Barro & Lee (1994)
	The proportion of the secondary school age population enrolled in school in 1970	Kelly (1997)
	The ratio of high school enrolment	Del Monte & Papagni (2001)
	Net secondary enrolment ratio	Cooray (2009)
Initial human capital	A weighted sum of the adjusted enrolment ratios in primary and secondary schools, and the percentage of 20-24 year old population enrolled in higher education	Landau (1983)
	Initial schooling per person as years of male and female secondary schooling	Barro & Lee (1994)
	Initial school enrolment as weighted sum of enrolement ratios in primary, secondary and higher education	Bose et al. (2007)
	Weighted sum of initial enrolment ratios	Moreno-Dodson (2008)
	Weighted sum of initial enrolment ratios	Bayraktar & Moreno-Dodson (2012)
Years of schooling	Average years of schooling in the total population	Folster & Henrekson (2001)
	The growth rate of the average years of schooling	Folster & Henrekson (2001)

Conditioning variables	Description	Authors
	The average years of schooling in the working age population	Romero-Avila & Strauch (2008)
	Annual growth rate of average years of schooling	Bergh & Karlsson (2010)
	Initial average years of schooling	Morozumi & Veiga (2016)
Literacy rate	Adult literacy rate in 1960	Barro (1991)
Initial life expectancy	Log of life expectancy at birth	Barro & Lee (1994)
	Log of life expectancy	Bose et al. (2007)
	Life expectancy at birth	Moreno-Dodson (2008)
Fertility	Log of the typical woman's prospective number of live births over her lifetime	Barro & Lee (1994)
	Fertility rate as births per woman	Folster & Henrekson (2001)
Population	Total population in thousands	Folster & Henrekson (2001)
	Population aged 0-15 and above 65 as a fraction of total population	Folster & Henrekson (2001)
	Urban population as a fraction of total population	Folster & Henrekson (2001)
Population growth	Average annual rate of population growth	Levine & Renelt (1992)
	The growth rate of population	Barro & Lee (1994)
	The change in the share of population that is under age 15	Barro & Lee (1994)
	Growth rate of population	Lin (1994)
	The rate of growth of population	Miller & Russek (1997)
	Annual population growth	Adam & Bevan (2005)
	Rate of growth of population	Nketia-Amponsah (2009)
	Population growth	Asimakopoulos & Karavias (2016)
	Population growth rate	Morozumi & Veiga (2016)
Labour force growth	Annual rate of growth of labour force participation	Lin (1994)
	Labour force growth	Kneller et al. (1999)
	Labour force growth	Bleaney et al. (2001)
	The growth rate of the labour force	Folster & Henrekson (2001)

Conditioning variables	Description	Authors
	Labour force growth	Moreno-Dodson (2008)
	Rate of labour growth	Abdullah et al. (2009)
	Average annual growth rate of the labour force	Bergh & Karlsson (2010)
Unemployment	Unemployment as a share of the labour force	Folster & Henrekson (2001)
Other indicators		
Political instability	The number of revolutions and coups per year	Barro (1991)
	The number of assassinations per million population per year	Barro (1991)
	An index for the number of revolutions and coups	Levine & Renelt (1992)
	Index of civil liberties	Levine & Renelt (1992)
	Assassinations per million	Easterly & Rebelo (1993)
	Revolutions and coups	Easterly & Rebelo (1993)
	War casualties per capita	Easterly & Rebelo (1993)
	The country's average number of revolutions per year	Barro & Lee (1994)
	The average of the indexes for political rights and civil liberties	Barro & Lee (1994)
	A dummy variable for countries that participated in at least one external war over 1960-85	Barro & Lee (1994)
	The fraction of time over 1960-85 that the country was involved in an external war	Barro & Lee (1994)
	Political instability index as the average of revolutions and coups, and political assassinations per million inhabitants per year	Bose et al. (2007)
	Bureaucracy index	Moreno-Dodson (2008)
	Political governance dummy	Nketia-Amponsah (2009)
	Political instability dummy	Nketia-Amponsah (2009)
Corruption	Crimes against the public administration per million employee	Del Monte & Papagni (2001)
Black market premium	The black market premium on foreign exchange	Barro & Lee (1994)

Conditioning variables	Description	Authors
	Premium in the black market for foreign exchange The black market premium on foreign exchange	Devarajan et al. (1996) Bose et al. (2007)
Globalization	Index of globalization using initial period value	Bergh & Karlsson (2010)
Economic freedom	Economic freedom using Fraser Institute index at intial period value	Bergh & Karlsson (2010
Dummy variable for government accountability	Dummy variables of high and low government accountability interacting with fiscal variables Dummy variables of high- and low- income countries using double interaction with accountability dummies Dummy variables of high- and low- level of law enforceability countries using double interaction with accountability dummies	Morozumi & Veiga (2016) Morozumi & Veiga (2016) Morozumi & Veiga (2016)
Dummy variable for socialist economy	Dummy variable for socialist economic system	Levine & Renelt (1992)
Energy consumption per capita		Landau (1983)
Dummy variable for climate zones	Mediterranean climate zone Tropical rain forest climate zone	Landau (1983) Landau (1983)
Dummy variable for regional group of countries	Dummy variable of African and Latin American countries Dummy variables for the sub-Saharan African and Latin American countries Regional dummy variables for Sub-saharan African, Latin American and East Asian countries. Cotinental dummy variables	Barro (1991) Levine & Renelt (1992) Barro & Lee (1994) Devarajan et al. (1996)
Dummy variable for fast-growing countries	Interactive dummy for fast-growing countries with fiscal expenditure	Bayraktar & Moreno-Dodson (2012)

1.4.1 Controlling economic conditions

Economic indicators appear repeatedly in the literature studying the relationship between economic development and public expenditure. This type of indicator can be mainly classified into six categories according to national income accounting which are economic outputs, investment variables, fiscal variables, trade variables, debt services and monetary variables.

1.) Economic outputs

As a control variable, economic outputs are used in terms of growth rates (lag of growth) and levels (initial GDP per capita). In terms of growth rates, Bleaney et al. (2001) use lagged value of per capita growth while Romero-Avila and Strauch (2008) include US GDP growth rates as a control variable.

In levels, most studies use initial per capita GDP, whereas some studies use per capita output (Adam & Bevan, 2005; Landau, 1983). Per capita output is used both in constant term and logarithmic form. Instead of using initial value of GDP per capita, Miller and Russek (1997) include lagged real per capita GDP as a proxy for economic output. Lagged GDP is also used in Kelly (1997), while Bergh and Karlsson (2010) use GDP level at the initial year of each subperiod. This type of control variable needs to be carefully included, since it has a direct association with dependent variable.

2.) Investment variables

Investment variables are used either as aggregate investment or private investment. They are always represented as a share of GDP. The key difference is whether public and private investment are included together which could slightly change the interpretation of the results. In addition, Folster and Henrekson (2001) also consider the ratios of private and national savings to GDP.

3.) Fiscal Variables

(3.1) Fiscal balances

Fiscal balances appear in the terms of budget balance (Abdullah et al., 2009; Bayraktar & Moreno-Dodson, 2012; Moreno-Dodson, 2008; Nurudeen & Usman, 2010) or budget surplus (Adam & Bevan, 2005; Bleaney et al., 2001; Bose et al., 2007; Kneller et al., 1999; Miller & Russek, 1997; Morozumi & Veiga, 2016). This

element measures the symmetry between taxes and government expenditure. It is an indication of financial stability of a particular country's government.

(3.2) Revenues

Tax revenue is used in Folster and Henrekson (2001), Adam and Bevan (2005), Bose et al. (2007), and Bergh and Karlsson (2010). In some studies, tax revenue is divided into distortionary tax (Abdullah et al., 2009; Bleaney et al., 2001; Kneller et al., 1999) and non-distortionary tax (Bleaney et al., 2001; Kneller et al., 1999; Miller & Russek, 1997).

Distortionary taxes affect the investment decisions of the agents and the steady-state rate of growth, whereas non-distortionary taxation does not affect either investment decision or the rate of growth (Kneller et al., 1999). Unclassified revenue is called other revenue (Bleaney et al., 2001; Kneller et al., 1999, Miller & Russek, 1997).

Alternatively, fiscal revenue to GDP is used instead of only taxes (Bayraktar & Moreno-Dodson, 2012; Moreno-Dodson, 2008). Non-tax revenue is incorporated in the study by Miller and Russek (1997), and Adam and Bevan (2005). Total government revenue is included in the studies of Miller and Russek (1997), Romero-Avila and Strauch (2008), and Morozumi and Veiga (2016).

There are a few other kinds of government revenue. For example, grants and seigniorage are included in Adam and Bevan (2005). Miller and Russek (1997) use disaggregated analysis of tax revenue which include corporate income, individual income, social security, and international taxes.

Classification of revenue or tax revenue is very important for empirical study on the relationship between public spending and growth while government budget constraint is taken into account, since this is related to the different estimates of the coefficients under the use of implicit financing element. The

classification of government revenue in the budget constraint will be used for further analysis.

4.) Trade Variables

Trade variables are used in four different forms which are trade ratio, growth rate of terms of trade (Barro & Lee, 1994; Bose et al., 2007), exports (Folster & Henrekson, 2001; Levine & Renelt, 1992; Nketia-Amponsah, 2009; Yuk, 2005) and imports (Folster & Henrekson, 2001). This type of variable can be considered as an impact of external sector of the economy.

5.) Debt services

Debt services are used in the form of debt servicing (Adam & Bevan, 2005; Singh & Sahni, 1984) or net lending (Adam & Bevan, 2005; Bleaney et al., 2001; Kneller et al., 1999). Interest on debt also appears in Adam and Bevan (2005). Cooray (2009) uses credit to GDP representing financial sector, whereas Levine and Renelt (1992) include growth rate and standard deviation of the growth rate of domestic credit in their study.

6.) Monetary variables

Monetary variables are in the forms of money supply (Bose et al., 2007; Easterly & Rebelo, 1993; Jiranyakul & Brahmasrene, 2007) or inflation rate. These proxies reflect the growth effects of monetary policy conducted by central bank through money market.

1.4.2 Controlling social impacts

Social indicators are also important in determining economic development. This group of indicators can be separated into human capital development and demographic variables.

1.) Human capital development

Human capital development is mainly measured by educational attainment and quality of health. The level of educational attainment can be represented in terms of school enrolment, years of schooling and literacy rate. Life expectancy and fertility are the main proxies for the quality of health. These indicators represent capacity of labour within a country.

2.) Demographic variables

There are three main demographic variables present in related studies which are population growth, labour force growth (Abdullah et al., 2009; Bleaney et al., 2001; Folster & Henrekson, 2001; Kneller et al., 1999; Moreno-Dodson, 2008) and unemployment. Alternatively, Lin (1994) uses growth rate of labour force participation. This set of variables may directly or indirectly reflect the pool of workforce in a particular nation.

1.4.3 Other effects

1.) Institutions variables

There are many indicators that could represent the quality of institutions within a country. A few examples of indicators are investigated in the studies on the relationship between public expenditure and growth. For example, political instability is included in several studies to capture quality of the institutions. Political instability

can be represented by wide range of indicators from revolutions and coups, assassinations, civil liberties, political rights, war casualties, bureaucracy, and political governance. These variables are used in the forms of indexes and dummy variable. Alternatively, corruption index is included in the study by Del Monte and Papagni (2001). Black market premium on foreign exchange appear in Barro and Lee (1994), Devarajan et al. (1996) and Bose et al. (2007). The remaining institution variables involve the issues on globalisation, economic freedom, government accountability and socialist economy.

2.) Environmental variables

Some variables can represent the environment in a specific area. Landau (1983) includes energy consumption per capita and dummy variable for climate zones as conditioning variables in the study.

3.) Group of countries dummy variable

For the fact that a selected group of countries might have a distinct characteristic, we might use dummy variable to capture such effect. For example, an interactive dummy variable for fast growing countries is analysed in Bayraktar and Moreno-Dodson (2012) in order to capture differential impacts of fiscal expenditure in this group of countries. Most of other studies use the dummy varibles to separate countries from different regions.

1.5 Defining economic development

Two main groups of dependent variables commonly used in the study of the relationship between public expenditure and economic development are the level of economic outputs and the growth rates of outputs. The list of variables representing economic development in related studies is in Table 1-6.

Table 1-6: List of variables representing economic development in related studies

Dependent variables	Description	Authors
Level of economic outputs		
Output	Gross national product	Ansari et al. (1997)
	Gross domestic product	Yuk (2005)
	Gross domestic product	Sevitenyi (2012)
Per capita output	GNP per capita	Singh & Sahni (1984)
	Real GDP per capita	Al-Faris (2002)
	Real GDP per capita	Wahab (2004)
	GDP per capita	Cooray (2009)
Growth rates of outputs		
GDP per capita growth	Growth rate of per capita GDP	Easterly & Rebelo (1993)
	Per capita growth	Kneller et al. (1999)
	Per capita GDP growth	Bleaney et al. (2001)
	Growth rate of per employee GDP	Del Monte & Papagni (2001)
	Growth in per capita income	Adam & Bevan (2005)
	Growth rate of GDP per capita	Moreno-Dodson (2008)
	Average annual growth rate of GDP per capita	Bergh & Karlsson (2010)
	Growth rate of GDP per capita	Bayraktar & Moreno-Dodson (2012)
	Growth rate of GDP per capita	Asimakopoulos & Karavias (2016)
Real per capita GDP growth	Per capita real GDP	Landau (1983)
	Growth rate of per capita real GDP	Barro (1991)
	Growth rate of real per capita GDP	Levine & Renelt (1992)
	Growth rate of real per capita GDP	Barro & Lee (1994)
	Growth rate in per capita real GDP	Hsieh & Lai (1994)
	Annual growth of real per capita GDP	Lin (1994)
	Per capita real GDP growth rate	Devarajan et al. (1996)
	Average rate of growth of real GDP per capita	Kelly (1997)
	Growth rate of real per capita GDP	Miller & Russek (1997)
	Average annual growth rate of GDP per head (1990 prices and exchange rates)	Folster & Henrekson (2001)
	Growth rate in per capita real GDP	Bose et al. (2007)
	Growth rate of real per capita GDP	Romero-Avila & Strauch (2008)

Dependent variables	Description	Authors
	Change in log of real GDP per capita	Abdullah et al. (2009)
	Rate of change of real GDP	Nketia-Amponsah (2009)
	Real output per capita growth	Christie (2014)
	Growth of real GDP per capita	Morozumi & Veiga (2016)
Changes in real GDP	First difference of log of real GDP	Jiranyakul & Brahmasrene (2007)
	Changes in real GDP	Nurudeen & Usman (2010)

1.5.1 The level of economic outputs

Economic output is a direct measurement of the size of the economy. The level of the outputs can be either directly measured or alternatively represented in per capita terms. Gross domestic product (GDP) is used in Sevitenyi (2012) and Yuk (2005), whereas gross national product is used in Ansari et al. (1997). There is a slight difference between GDP and GNP over geographical boundary and citizenship; however, it should not generate results that are profoundly different from one another. Level of output per capita is measured in terms of per capita national income in Singh and Sahni (1984) or per capita GDP (Al-Faris, 2002; Cooray, 2009; Wahab, 2004).

1.5.2 The growth rates of outputs

Similar to the level of economic outputs, the rates of growth are calculated from either the level of outputs or output per capita; for example, growth of output is measured by a change in real GDP in Jiranyakul and Brahmasrene (2007) and Nurudeen and Usman (2010), and per capita growth is measured in terms of per capita GDP growth in nominal term and real per capita GDP growth. Real per capita GDP growth is calculated by using constant price. This requires base year in which can be different across countries. Alternatively, the growth rate of per employee GDP is analysed in Del Monte and Papagni (2001).

1.6 Estimation methods

The choices of static models, dynamic models and causality test were employed in the related studies as shown in Table 1-7. The dynamic panel data model and causality test are frequently used in most recent studies.

Early studies are inevitably subject to limitation on data availability. Most of them use either cross-section or time-series data. Since countries are greatly different in economic structure, judiciary system and many other aspects, Ram (1986) argued that cross-section models implying strong parametric restriction across countries can be rigid and unrealistic.

In many cases, the cross-section data is an average value over certain period of time. Folster and Henrekson (2001) have discussed several other problems from cross-section studies using long time spans. The first and the most important problem is potentially severe simultaneity. The level of public spending is likely to be influenced by demographics; for example, increase in income will expand expected life expectancy which finally results in higher public spending especially on healthcare and social welfare. Secondly, this can also cause an endogenous selection of tax policy, depending on each country's experience on growth effects of fiscal changes. Thirdly, there is inefficiency from eliminating variation that might exist within a country over a long period of time.

Hsiao (2003) has discussed several advantages of using panel data over cross-section and time-series data. Firstly, the efficiency of econometric estimates is improved due to the use of large number of data points, resulting in the increase of the degrees of freedom and the reduction of collinearity among the set of regressors. Secondly, the effects of missing or unobserved variables are better controlled by utilising both the intertemporal dynamics and individuality of the samples under investigation. For example, the unobserved characteristics that vary across individuals but unchanged through time can be dealt with by taking the first difference of individual observations over time.

The issues of heterogeneity and selectivity bias might arise in using panel data as discussed by Hsiao (2003). The estimates could be biased if there is heterogeneity among cross-sectional units on different slopes and intercepts. In our study, heterogeneity bias is taken into account by including country and year fixed effects and separating countries into groups of

developing and high-income countries. Selectivity bias is not a concern in our cross-country study.

While taking into account the role of government budget constraint, the possible endogenity problem and non-linearity as mentioned earlier are also considered in our study of the relationship between growth and public spending. As a result, instrumental variable (2SLS) and ordinary least squares estimates are both analysed. The non-linearity is futher investigated by the inclusion of the squared value of public spending.

The table 1-7 below combines the list of studies with their estimation methods in chronological order.

Table 1-7: List of estimation methods used in related studies

Authors	Estimation methods	Description
Landau (1983)	Two-stage least squares Stepwise regression	
Singh & Sahni (1984)	Granger method	
Barro (1991)	Ordinary least squares (OLS)	The standard errors for the coefficients are based on White's (1980) heteroshedasticity-consistent covariance matrix.
Levine & Renelt (1992)	Ordinary least squares (OLS) Extreme-bounds analysis	A variant of Leamer's (1983) extreme-bounds analysis (EBA) is used for testing the robustness of coefficients estimates to alterations in the set of control variables.
Easterly & Rebelo (1993)	Cross-section regression Panel regression	Least squares regression with White's (1980) heteroskedastic-consistent standard errors Pooled regression with decade averages Pooled cross-section time series with annual data
Barro & Lee (1994)	Seemingly unrelated technique Instrumental estimates	
Hsieh & Lai (1994)	Examination of inter-temporal interactions	Testing for stationarity Granger causality test Impulse response functions Variance decompositions
Lin (1994)	Simultaneous equation model	Ordinary least squares (OLS) Park (1967) autoregressive estimation

Authors	Estimation methods	Description
		2SLS 3SLS
Devarajan et al. (1996)	Ordinary least squares (OLS)	Standard errors are adjusted by the Hansen and Hodrick's (1980) method of correlation correction.
Ansari et al. (1997)	Causality test	Granger causality test Holmes-Hutton causality test
Kelly (1997)	Ordinary least squares (OLS)	
Miller & Russek (1997)	Ordinary least squares (OLS) Fixed-effect model Random-effect model	
Kneller et al. (1999)	5-year average two-way fixed effects	Two-way fixed effects model
Bleaney et al. (2001)	Static and dynamic panels	LSDV: 2 way fixed effects; Five-year averages Dynamic panel with eight lags of annual data Annual dynamic panels instrumental variables
Del Monte & Papagni (2001)	Dynamic panel data econometric method	LSDV 2SLS Random effects
Folster & Henrekson (2001)	Panel regressions Extended extreme bounds analyses	Ordinary least squares (OLS) Two-way fixed effects First differences 2SLS
Al-Faris (2002)	Granger causality test	Unit root and cointegration test Granger causality test
Wahab (2004)	Error-correction model (ECM)	
Adam & Bevan (2005)	Fixed effects model	Fixed effects estimation with fiscal effects lagged
Yuk (2005)	Granger causality test	Vector autoregression
Bose et al. (2007)	Growth regressions	Seemingly unrelated regression
Jiranyakul & Brahmasrene (2007)	Granger causality test Least square method	
Moreno-Dodson (2008)	Ordinary least square (OLS) GMM Seemingly unrelated regression	
Romero-Avila & Strauch (2008)	Panel cointegration A distributed lag model	

Authors	Estimation methods	Description
Abdullah et al. (2009)	Mixed methods for panel data	Ordinary least squares (OLS) Within groups First differenced GMM System GMM
Cooray (2009)	GMM estimation Seemingly unrelated regression	
Nketia-Amponsah (2009)	OLS and Granger causality test	
Bergh & Karlsson (2010)	Panel regressions	Ordinary least squares (OLS) Two-way fixed effects Bayesian averaging of classical estimates
Nurudeen & Usman (2010)	Cointegration Error correction methods (ECM)	
Bayraktar & Moreno-Dodson (2012)	OLS and dynamic GMM Seemingly unrelated regression	
Sevitenyi (2012)	Granger (1969) causality	Unit root and cointegration test Granger causality test
Christie (2014)	Panel regressions	Two-way fixed effects model One-step system GMM
Asimakopoulos & Karavias (2016)	Non-linear panel GMM	Non-linear panel GMM approach of Seo and Shin (2014) allowing for a threshold effect with endogenous regressors and threshold variable
Morozumi & Veiga (2016)	Dynamic panel data model	System GMM estimations

1.7 Findings of previous literature

The results of the studies on the relationship between public expenditure and economic growth can be classified by countries into three categories which are a group of all countries, a particular group of countries and an individual country. (see Table1-8)

Table 1-8: The results from the literature

Authors	Growth-promoting variables	Growth-deteriorating variables	Variables with insignificant /inconsistent effect / for causality test (C)
All countries			
Landau (1983)	Total investment in education	Government consumption expenditure	
Barro (1991)		Government consumption	Public investment
Levine & Renelt (1992)			Government consumption
Easterly & Rebelo (1993)	Transportation and communication investment General government investment		Total public enterprise investment
Barro & Lee (1994)		Government consumption	
Lin (1994)	Government consumption		Non-productive expenditure
Kelly (1997)	Public Investment Housing expenditure Social security expenditure	Health expenditure Education expenditure	
Miller & Russek (1997)	Tax-financed government expenditure	Debt-financed government expenditure Government deficit	
Cooray (2009)	Government size and government quality		
Christie (2014)		Government spending above 33 percent of GDP	
Asimakopoulos & Karavias (2016)	Government spending below estimated threshold	Government spending above estimated threshold	
Morozumi & Veiga (2016)	Capital spending with accountable government Current spending financed by revenue Capital spending financed by revenue		Current spending financed by deficit
Developed countries			
Hsieh & Lai (1994)			Government spending (C)

Authors	Growth-promoting variables	Growth-deteriorating variables	Variables with insignificant /inconsistent effect / for causality test (C)
Kneller et al. (1999)	Productive government expenditure Budget surplus	Distortionary taxation Initial GDP	
Bleaney et al. (2001)	Productive expenditure Other expenditure Budget surplus	Distortionary taxation	
Folster & Henrekson (2001)		Government expenditure	
Wahab (2004)			Government expenditure (C)
Bergh & Karlsson (2010)		Government expenditure	
Developing countries			
Devarajan et al. (1996)	Current expenditure	Capital expenditure Defence expenditure Economic infrastructure expenditure	Total expenditure Health expenditure Education expenditure
Adam & Bevan (2005)		Fiscal deficits at 1.5%GDP	
Bose et al. (2007)	Government capital expenditure Education expenditure		Current expenditure
Moreno-Dodson (2008)	Private investment Education spending Health spending		
Bayraktar & Moreno-Dodson (2012)	Productive and core spending in fast growing economies		
Regional studies			
Ansari et al. (1997)			Government expenditure(C)
Al-Faris (2002)			Government expenditure(C)
Romero-Avila & Strauch (2008)	Public investment	Government consumption Direct taxation	

Authors	Growth-promoting variables	Growth-deteriorating variables	Variables with insignificant /inconsistent effect / for causality test (C)
Abdullah et al. (2009)	Health expenditure Education expenditure	Defence expenditure Distortionary taxation Budget balance	
Individual countries			
Singh & Sahni (1984)			Public expenditure (C)
Del Monte & Papagni (2001)		Quality of public institution affected by corruption	
Yuk (2005)			Government spending (C)
Jiranyakul & Brahmasrene (2007)	Government expenditure One-period lag of government expenditure		
Nketia-Amponsah (2009)	Health spending Infrastructure spending		Education spending
Nurudeen & Usman (2010)	Government expenditure on transport and communication Government expenditure on health	Government total capital expenditure Total recurrent expenditure Government expenditure on education	
Sevitenyi (2012)			Government expenditure (C)

1.7.1 All countries

Early studies usually investigate the relationship between public expenditure and economic growth by including all countries with different income levels together. They also focus mainly on the aggregate level of government expenditure, whereas later studies shift their interest towards the components of government expenditure. Recent studies might also compare the estimates of a group of all countries with a group of developing countries and a group of high-income countries. The findings from Landau (1983) showed that total investment in education is growth-promoting, whereas government consumption

expenditure has a negative effect on growth. The negative effect on growth of government consumption was also found by Barro (1991), and Barro and Lee (1994). In contrast, Lin (1994) showed that government consumption is growth-promoting, whereas non-productive expenditure depending on a particular group of countries has insignificant and inconsistent effect on growth. Kelly (1997) has shown that different types of public spending exert different impacts on economic growth. Public investment, housing expenditure and social security expenditure all affect growth positively. On the contrary, health and education expenditure affect economic growth negatively. The effect of education expenditure on growth in Kelly (1997) contradicts with the results from Landau (1983). Transportation and communication investment, and general government investment are found to have positive effects on growth in the study of Easterly and Rebelo (1993)

Apart from only direct measurement of public expenditure, Cooray (2009) argues that both government size and quality (governance) have significantly positive effects on economic growth. The part of government quality raises the concern of the role of institution. Considering the role of government accountability, Morozumi and Veiga (2016) have found that capital spending by accountable government is conducive to growth.

The threshold level of government could play an important part in determining growth effect of public spending. Christie (2014) has found that government spending that exceeds 33 %GDP can have deteriorating effect on growth. Similarly, Asimakopoulos and Karavias (2016) find that government spending below threshold level can be growth-enhancing while the spending at above threshold level becomes growth-decreasing.

The fiscal-growth effects can also be sensitive to the sources of financing public spending. Miller and Russek (1997) have found positive effect on growth from tax-financed government expenditure, while debt-financed government expenditure can be harmful to growth.

1.7.2 Particular group of countries

For a particular group of countries, we may classify countries according to income level or geographical location. The examples of developed countries, developing countries and regional studies are included.

1.) Developed countries

The studies of developed countries mainly include OECD and G-7 countries. Hsieh and Lai (1994) concluded that the effects of government spending on economic growth in G-7 countries are inconsistent across countries and time. However, Kneller et al. (1999) and Bleaney et al. (2001) reached relatively similar conclusion for OECD countries. In both studies, productive expenditure is growth-promoting, whereas distortionary taxation is growth-deteriorating.

Focussing on high-income countries, Folster and Henrekson (2001), and Bergh and Karlsson (2010) have found negative growth impacts of government expenditure.

With error correction model, Wahab (2004) showed that government expenditure declines more proportionately with a slowing economy, whereas expenditure increases less with an accelerating economy.

2.) Developing countries

According to Bose et al. (2007), government capital expenditure, education expenditure and private investment have positive impacts on growth in developing countries. On the contrary, current expenditure has an insignificant effect on economic growth. Moreno-Dodson (2008) supports the finding from Bose et al. (2007) showing that education and health spending are growth-enhancing.

In contrast with Bose et al. (2007), Devarajan et al. (1996) have found that capital expenditure is growth-deteriorating. They have claimed that the negative impact is due to misallocation of public spending in favour of capital expenditure.

Some studies tried to find the condition where expenditure can promote growth. Adam and Bevan (2005) suggested that fiscal deficit at 1.5%GDP is the threshold level for the effective fiscal policy on growth. At higher level of deficits, growth pay off could disappear. Bayraktar and Moreno-Dodson (2012) suggested that only in fast growing economies is productive and core spending conducive to growth.

3.) Regional studies

Focussing on Asian economies, Abdullah et al. (2009) found that health and education expenditure are growth-promoting, whereas defence expenditure and distortionary taxation are both growth-deteriorating.

With a group of EU-15 countries, Romero-Avila and Strauch (2008) have found positive impacts on growth from public investment while government consumption and direct taxation are growth-deteriorating.

Ansari et al. (1997) and Al-Faris (2002) tried to identify the causation between expenditure and growth. With the Gulf Co-operation Council countries from Al-Faris (2002), economic growth pre-determines expanding role of the government. To test Keynesian hypothesis, Ansari et al. (1997) found no evidence of government expenditure causing national income in African countries.

4.) Individual countries

Studying the relationship between growth and public expenditure by looking at any particular country is a way to clearly identify specific effects of government on growth for recommending national policy prescription.

Singh and Sahni (1984) found that the direction of causality between public expenditure and growth in India is inconsistent. In contrast, government spending Granger-causes growth in the case of the United Kingdom (Yuk, 2005).

There is little more evidence supporting Keynesian hypothesis. Government expenditure and one-period lag of government expenditure are growth-promoting in the case of Thailand (Jiranyakul & Brahmasrene, 2007). In the case of Nigeria, Sevitenyi (2012) also supported Keynesian approach in which causality runs from government expenditure to growth. At the disaggregated level of Nigerian public spending: health expenditure, and transportation and communication expenditure are growth-promoting, whereas: capital expenditure, recurrent expenditure and education expenditure are growth-retarding (Nurudeen & Usman, 2010). Health and infrastructure spending are growth-promoting in Ghana, whereas education spending has insignificant effect on growth (Nketia-Amponsah, 2009).

Furthermore, the role of institution in determining growth was shown by Del Monte and Papagni (2001) where corruption has negative effects on growth through private investment and efficiency of expenditure on public investment.

Even though previous studies have shown contradicting results on the impacts of public expenditure on economic growth, there are a substantial number of similar findings from cross-country studies. First, there is evidence of causality running from public expenditure to economic growth. Secondly at aggregate level, private investment, public investment and productive government expenditure are growth-enhancing, whereas distortionary tax and recurrent expenditure are growth-deteriorating. Thirdly, health, housing and education expenditure are growth-promoting at disaggregated level. Finally, defence expenditure has negative impact on growth.

1.8 Further analysis on fiscal policy impacts

Further analysis of this fiscal-growth study in Chapter 2 is primarily based on Bose et al. (2007) where several distinctive features were focussed. First, they focussed on a disaggregated level of government expenditure in developing countries. Second, the inclusion of conditioning variables was distinctively

systematic, since they were separated into common conditioning variables in growth regression and policy variables. Thirdly, the role of government budget constraint was taken into account.

There are at least a few improvements from Bose et al. (2007) which we have extended in Chapter 2. First, more extensive group of developing countries can be included as well as considering high-income countries. Second, different time periods apart from decade averages are analysed. In this way, we can implement panel data analysis by using annual data which is different from the cross-section data they have used. Thirdly, the alternative techniques for panel regression are introduced as a comparison. Especially, the instrumental estimates are implemented to solve for potential endogeneity of some of the control variables. Lastly, the non-linear impact of public spending on growth has been investigated by including the squared terms. The regression analysis of our study includes control variables which mainly align with Bose et al. (2007). The discussion on the rationale for inclusion of these control variables are further discussed in Chapter 2.

In Section 3.1 of Chapter 3, the government budget constraint is further investigated in a similar framework as appeared in Kneller et al. (1999). While Chapter 2 and Section 3.1 of Chapter 3 focus on permanent growth effects of fiscal changes without considering transitional dynamics, the study in Section 3.2 of Chapter 3 allows for Solow-type transitional dynamics where the effects of fiscal policy could be persistent. In order to do this, the long-run GDP impacts of changes in the total government expenditure and in the shares of different spending functions are considered following Gemmell et al. (2016).

In other words, the relationship between public expenditure and economic development would be investigated according to three different issues for groups of countries with different levels of income.

First, a disaggregated analysis of the relationship between public spending by function and economic growth is investigated under the framework proposed by Bose et al. (2007) with the extension of the samples from developing to high-income countries while taking the issues of endogeneity and non-linearity into account. Secondly, the role of government budget constraint in the framework of public expenditure and growth is examined using different implicit financing elements appeared in Kneller et al. (1999). While their study

limit to high-income OECD countries, we compare high-income OECD with developing countries. Thirdly, the composition of public spending and long-run GDP per capita has been investigated using pooled mean group (PMG) estimators according to the methodology in Gemmell et al. (2016). This is also extended from high-income OECD to developing countries.

In the second chapter, the data on public spending and its composition is firstly analysed. Then, regression analysis of public spending and economic growth is investigated according to groups of countries with different income levels. In the third chapter, the role of government budget constraint is taken into account when considering the relationship between public expenditure and economic growth. The latter part of the third chapter investigates how change in public spending may have an impact on long-run GDP level. We also later on refer to specific literature for this part in the third chapter. The next chapter will discuss a disaggregated analysis of public spending and economic growth.

Chapter 2: A disaggregated analysis of public spending and economic growth

In this chapter, we look at both the data analysis of public spending and the regression analysis of public expenditure and economic growth. Section 2.1 discusses the empirical evidence of public spending according to the sample groups comprising 75 countries with different income levels that can be seen in Table 2-1. These groups will be referred to as Sample 1. The whole sample set of countries comprises 37 developing countries and 38 high-income countries. The high-income group can be further broken down into 31 high-income OECD countries and 7 high-income non-OECD countries.

Section 2.2 investigates the permanent growth effects of increased government expenditure in the public-policy endogenous growth model using Sample 1. We use the main set of control variables that appear in Bose et al. (2007). The study in Section 2.2 will be referred to as Study 1.

2.1 Empirical evidence of public spending: size and composition

This section analyses the trend of public spending in groups of Sample 1 countries with different income levels. We measure total government expenditure and classify government spending into types. These types of government spending are categorised by the functions or objectives that government units intend to accomplish.[1] We use data from 75 Sample 1 countries according to the availability of fiscal data from Government Finance Statistics (GFS) and other control variables in our regression analysis.[2]

The fiscal data from GFS is subject to change in the analytical framework by the International Monetary Fund (IMF) from the GFSM 1986 to the GFSM 2001.[3] Our government revenue data is unaffected as it relies exclusively on the GFSM 2001 framework.

[1] The words 'type' and 'function' appear interchangeably in our discussion. Sometimes, it might be referred to as 'category'.
[2] The GFS data in our analysis is mainly extracted from the online database of the UK Data Service.
[3] GFSM stands for Government Finance Statistics Manual.

Table 2-1: List of 75 Sample 1 countries (Study 1)

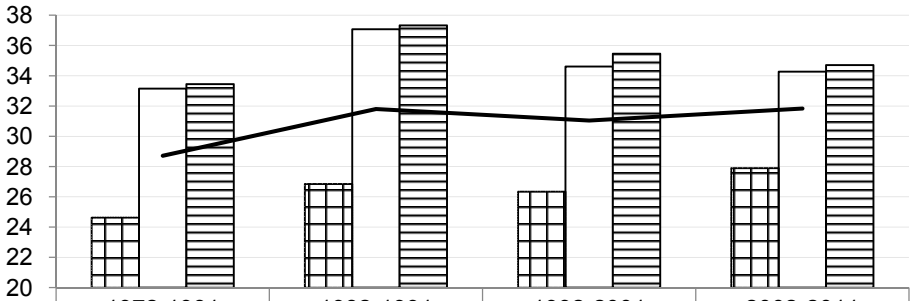
	Country	Income group		Country	Income group		Country	Income group		Country	Income group
1	Argentina	Upper middle income	21	Malaysia	Upper middle income	38	Australia	High-income: OECD	58	New Zealand	High-income: OECD
2	Bangladesh	Low income	22	Mali	Low income	39	Austria	High-income: OECD	59	Norway	High-income: OECD
3	Belarus	Upper middle income	23	Mauritius	Upper middle income	40	Belgium	High-income: OECD	60	Poland	High-income: OECD
4	Bhutan	Lower middle income	24	Moldova	Lower middle income	41	Canada	High-income: OECD	61	Portugal	High-income: OECD
5	Bolivia	Lower middle income	25	Mongolia	Lower middle income	42	Chile	High-income: OECD	62	Slovak Republic	High-income: OECD
6	Bulgaria	Upper middle income	26	Morocco	Lower middle income	43	Czech Republic	High-income: OECD	63	Slovenia	High-income: OECD
7	Burkina Faso	Low income	27	Nepal	Low income	44	Denmark	High-income: OECD	64	Spain	High-income: OECD
8	Burundi	Low income	28	Pakistan	Lower middle income	45	Estonia	High-income: OECD	65	Sweden	High-income: OECD
9	Cameroon	Lower middle income	29	Panama	Upper middle income	46	Finland	High-income: OECD	66	Switzerland	High-income: OECD
10	Costa Rica	Upper middle income	30	Paraguay	Lower middle income	47	France	High-income: OECD	67	United Kingdom	High-income: OECD
11	Dominican Republic	Upper middle income	31	Romania	Upper middle income	48	Germany	High-income: OECD	68	United States	High-income: OECD
12	Egypt, Arab Rep.	Lower middle income	32	South Africa	Upper middle income	49	Greece	High-income: OECD	69	Croatia	High-income: nonOECD
13	Ethiopia	Low income	33	Syrian Arab Republic	Lower middle income	50	Hungary	High-income: OECD	70	Cyprus	High-income: nonOECD
14	Georgia	Lower middle income	34	Thailand	Upper middle income	51	Ireland	High-income: OECD	71	Latvia	High-income: nonOECD
15	India	Lower middle income	35	Tunisia	Upper middle income	52	Israel	High-income: OECD	72	Lithuania	High-income: nonOECD
16	Indonesia	Lower middle income	36	Turkey	Upper middle income	53	Italy	High-income: OECD	73	Russian Federation	High-income: nonOECD
17	Iran, Islamic Rep.	Upper middle income	37	Ukraine	Lower middle income	54	Japan	High-income: OECD	74	Trinidad and Tobago	High-income: nonOECD
18	Jamaica	Upper middle income				55	Korea, Rep.	High-income: OECD	75	Uruguay	High-income: nonOECD
19	Jordan	Upper middle income				56	Luxembourg	High-income: OECD			
20	Lesotho	Lower middle income				57	Netherlands	High-income: OECD			

Note: All Sample 1 countries comprise 37 developing countries (low-income and middle-income) and 38 high-income countries (OECD and non-OECD)

Our public expenditure data requires some adjustment; this has been taken into account, particularly with regard to general public services, and transportation and communication spending. Further details can be found in Appendix 1.

2.1.1 The size of government

To measure the size of government, the ratio of total public spending over GDP is a proxy which indicates how large a country's public sector is relative to its economy. For example, the unweighted average of total spending as a percentage of GDP between 1972 and 2012 suggests that, on average, the size of the government in Sample 1 countries is almost one-third (31.14%) of its economy. The size of government in high-income Sample 1 countries (34.82%) is higher than that of developing Sample 1 countries (26.63%). This may indicate that governments play relatively larger or broader roles in rich countries' economies than they do in poor ones.



	1972-1981	1982-1991	1992-2001	2002-2011
Developing	24.64	26.86	26.35	27.90
High-income	33.14	37.07	34.61	34.27
OECD	33.46	37.33	35.47	34.72
All countries	28.71	31.80	31.04	31.83

Figure 2-1: Unweighted 10-year averages of total public spending as percentages of GDP for groups of Sample 1 countries 1972-2011

In Figure 2-1, the 10-year averages of total spending indicate that the size of government in Sample 1 countries seems to increase significantly from the 1970s to the 1980s. Its relative size to GDP is lower in the 1990s, but its size in 2000s is still higher than it was in the 1970s. The increasing trend of government spending is obvious in developing Sample 1 countries but not in Sample 1 countries in other income groups. The ratio of public spending to GDP

in developing Sample 1 countries increases from 24.64% between 1972 and 1981 to 27.90% between 2002 and 2011.

Although government size in high-income Sample 1 countries is greater than in developing Sample 1 countries, this does not necessarily apply to all types of public spending by function. Table 2-2 shows that there are two main functions of spending in high-income Sample 1 countries, namely health and social welfare, which are relatively higher than in developing Sample 1 countries. Spending on general public services and defence in developing Sample 1 countries is, in contrast, higher than it is in high-income Sample 1 countries. The other functions of spending (transportation and communication, and education) seem to be similar regardless of level of income across groups of Sample 1 countries. The ratio to GDP of each type of spending in high-income Sample 1 countries is very similar to that in high-income OECD Sample 1 countries.

Table 2-2: Unweighted annual averages of public spending by type as percentages of GDP for groups of Sample 1 countries between 1972 and 2012

	All	Developing	High-income	OECD
Total spending	31.14	26.63	34.82	35.36
General public services	3.38	3.85	2.99	2.93
Defence	2.34	2.51	2.21	2.28
Transportation and communication	1.61	1.64	1.60	1.63
Education	3.29	3.43	3.17	3.24
Health	2.72	1.67	3.58	3.72
Social welfare	8.89	3.84	12.73	13.05
Other spending	8.91	9.70	8.55	8.52

2.1.2 Disaggregated analysis of public spending

Even though the increasing trend of public spending is obvious in developing Sample 1 countries, some types of spending at the disaggregated level may decrease over time. This section uses 10-year averages to examine each type of public spending trend in both high-income and developing Sample 1 countries. We investigate trends in six main types of public spending: general public services; defence; transportation and communication; education; health; and social welfare. These types of spending will also be considered in our fiscal-growth regression analysis in Section 2.2.

Figure 2-2 shows that spending on social welfare and health has increased substantially in the group of all Sample 1 countries during the last four decades. Social welfare spending increased from 6.64%GDP in the 1970s to 10.26%GDP in the 2000s. This reflects the crucial role played by governments in implementing social policy to counteract the problem of ageing populations. In contrast, spending on defence, and transportation and communication has decreased during the past four decades. The level of spending on general public services and education is relatively stable.

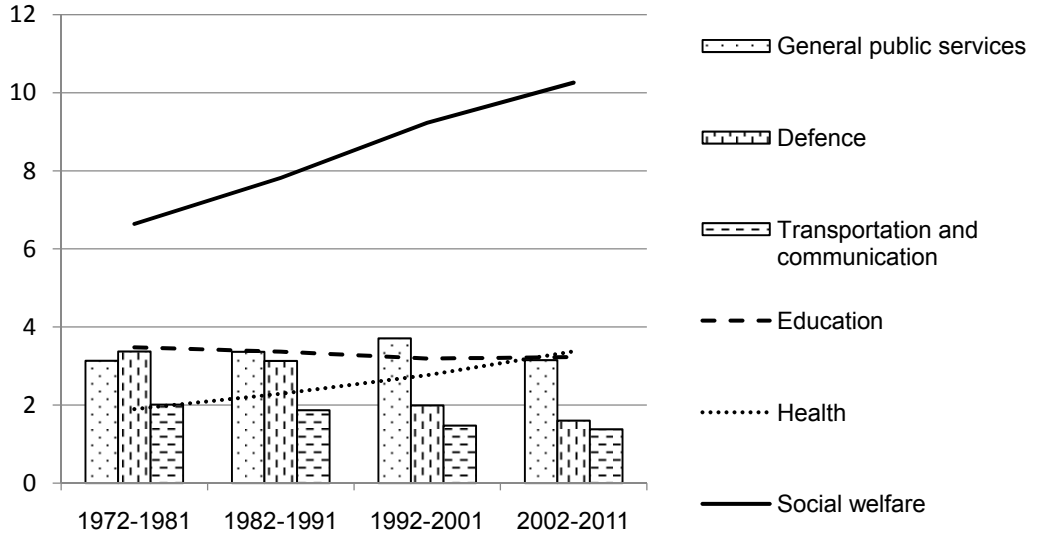


Figure 2-2: Unweighted 10-year averages of public spending by type as percentages of GDP for group of all Sample 1 countries

In Figure 2-3, we can see that social welfare spending increased steadily from 1.69%GDP in the 1970s to 6.27%GDP in the 2000s in developing Sample 1 countries. This might reflect changing population structures, due to increases in the ratios of dependents per adult. Defence, and transportation and communication spending decreased over time. Spending on general public services, health and education did not change significantly.

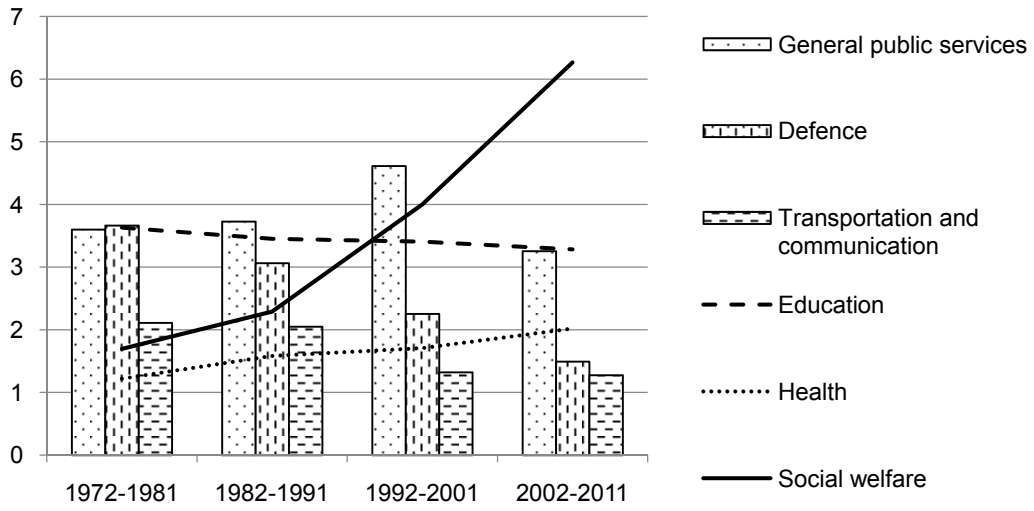


Figure 2-3: Unweighted 10-year averages of public spending by type as percentages of GDP for developing Sample 1 countries

As we can see from Figure 2-4, health spending in high-income Sample 1 countries increased over time, whereas defence, and transportation and communication spending decreased during the same period. General public services and education spending remained relatively consistent. Spending on social welfare remained high relative to other types of spending. The findings are similar in high-income OECD Sample 1 countries.

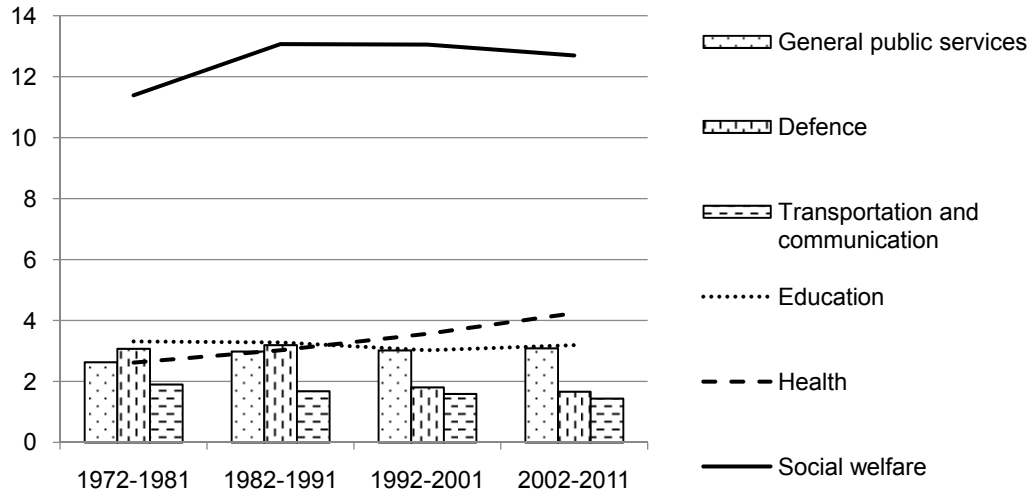


Figure 2-4: Unweighted 10-year averages of public spending by type as percentages of GDP for high-income Sample 1 countries

In summary, social welfare spending has become an increasingly important part of governments' budgets. The evidence for this is both a rising trend of spending in developing Sample 1 countries and consistently high levels of social welfare spending in high-income Sample 1 countries. Spending on defence, and transportation and communication decreased as a percentage of GDP. In addition to looking at the ratio of public spending to GDP, we might compare each type of spending to the total sum of spending. The composition of public spending will then be investigated further in the next subsection.

2.1.3 The composition of public spending

The composition of public spending reveals how important each type of spending is from the perspective of the government. This structure could be highly dependent on a country's particular needs at its current stage of development (subject to that country's demographics). For the set of all Sample 1 countries, social welfare (26.34%), general public services (11.67%) and education (10.82%) spending are among the spending types with the highest ratios to total spending. On the other hand, spending on general public services (15.10%), social welfare (13.71%) and education (12.96%) are the types with the highest ratios to the total spending of developing Sample 1 countries. In high-income Sample 1 countries, social welfare (35.96%), health (10.11%) and education (9.07%) spending are the types of spending with the highest ratios to total spending. These three types of spending also have the highest ratios to the total spending of high-income OECD Sample 1 countries (see Table 2-3).

Table 2-3: Unweighted annual averages of spending by type as percentages of total spending for groups of Sample 1 countries between 1972 and 2012

	All	Developing	High-income	OECD
General public services	11.67	15.10	8.88	8.54
Defence	8.14	9.89	6.79	6.93
Transportation and communication	5.28	6.14	4.59	4.62
Education	10.82	12.96	9.07	9.15
Health	8.41	6.32	10.11	10.40
Social welfare	26.34	13.71	35.96	36.21
Other spending	29.35	35.88	24.61	24.14

The following figures demonstrate how the composition of public spending in Sample 1 countries evolves over time.

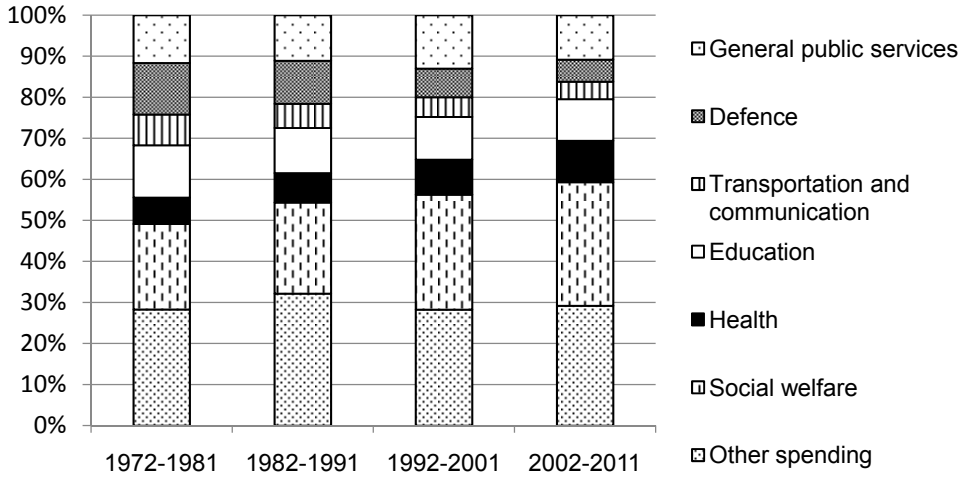


Figure 2-5: Unweighted 10-year averages of public spending by type as percentages of total spending for group of all Sample 1 countries

** Other expenditure includes all types of spending which do not fit into any of the six categories above.

In terms of 10-year averages for the group of all Sample 1 countries (Figure 2-5), social welfare, general public services and education spending are among the highest types of spending. The proportions of social welfare and health spending have increased dramatically over time.

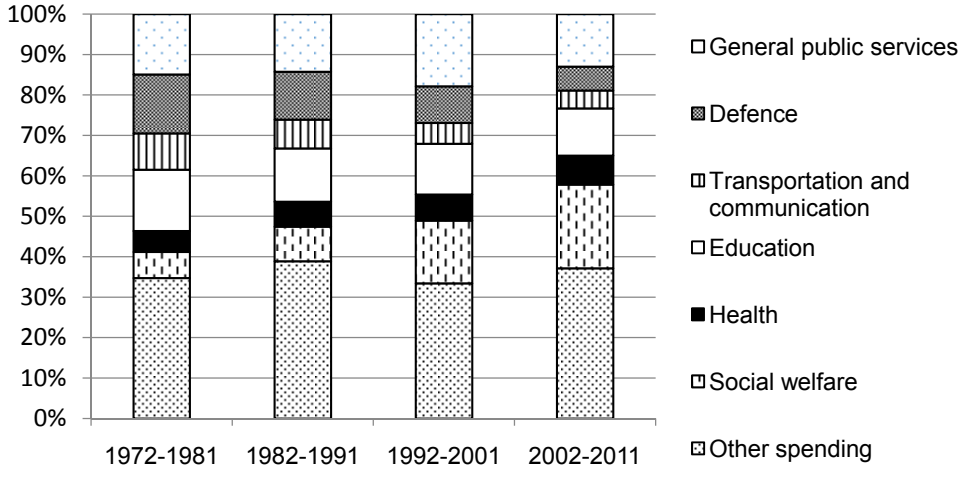


Figure 2-6: Unweighted 10-year averages of public spending by type as percentages of total spending for developing Sample 1 countries

** Other expenditure includes all types of spending which do not fall into any of the six categories above.

As shown in Figure 2-6, spending on general public services and social welfare are among the highest types of spending in developing Sample 1 countries. Social welfare spending, in particular, has increased substantially in recent decades. In contrast, the proportions of defence, and transportation and communication spending have been decreasing. The education, health and general public services spending ratios seem to be constant over time.

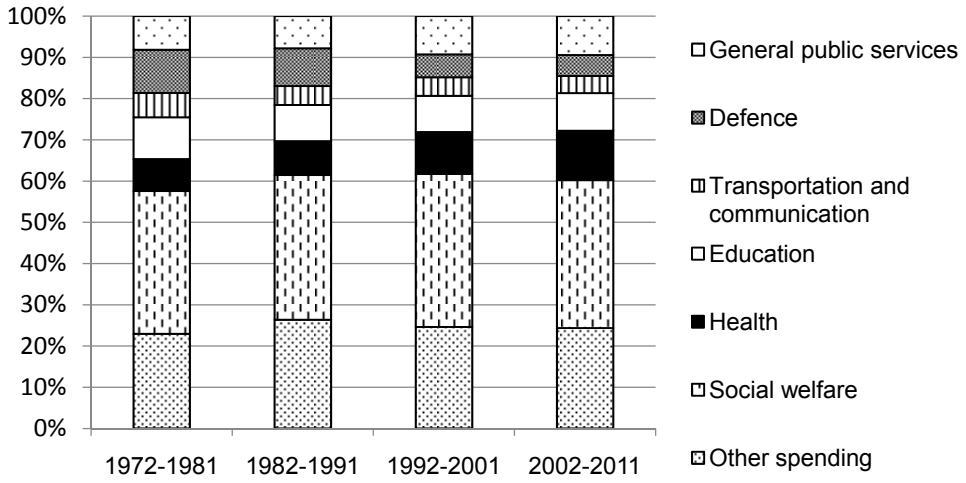


Figure 2-7: Unweighted 10-year averages of public spending by type as percentages of total spending for high-income Sample 1 countries

** Other expenditure includes all types of spending which do not fall into any of the six categories above.

In high-income Sample 1 countries (see Figure 2-7), social welfare, health and education attract some of the highest amounts of expenditure. While the ratios of spending on healthcare and general public services to total spending have increased in recent years, the ratios of transportation and communication, and defence spending have decreased. The proportions of education and social welfare spending have remained approximately the same over time.

2.2 A regression analysis of public expenditure and economic growth (Study 1)

The relationship between public expenditure and economic growth needs to be empirically examined in order to determine the role of the state in stabilising its economy through business cycles. Countries at different developmental stages

will have different concerns and these should be addressed by efficiently allocating spending on specific types of government expenditure.

Early public expenditure and economic growth studies focussed on the aggregate level of expenditure, while paying attention to a combination of developed (high-income) and developing countries. The relationship between growth and public spending in these studies was concluded to be inconsistent in terms of causation between government expenditure and economic growth. Many of these studies proved that public expenditure affected economic growth adversely. For instance, Landau (1983) found a negative relationship between the share of government consumption expenditure in GDP and the rate of growth per capita GDP in 104 countries between 1961 and 1976. In contrast, more recent studies have shifted the focus towards analysis at a disaggregated level of public expenditure. They have shown that different types of public expenditure exert distinct effects on economic growth (Abdullah et al., 2009; Bose et al., 2007; Devarajan et al., 1996; Nurudeen & Usman, 2010). The different groups of countries were also examined using more sophisticated dynamic models employing various econometric techniques. However, the regression results still seem to be highly distinguishable.

In Section 2.1, the analysis of public expenditure data has shown that some distinct combinations of the types of government expenditure occur at different stages of economic development. For example, social welfare spending is a significant part of government expenditure in high-income Sample 1 countries due to ageing populations. The proportions of transportation and communication, and education spending in the government budgets of developing Sample 1 countries are significantly higher than those of high-income Sample 1 countries. This reflects the need for investment in infrastructure and human capital in the early stages of a country's development. Since the government plays a crucial role in boosting and stabilising the economic growth of its country, it is essential to understand the link between public expenditure and economic growth at a disaggreagated level. In this section, we investigate such a link by using empirical data relating to public expenditure by function according to the IMF's definitions from the Government Finance Statistics. The main set of control variables aligns with the variables used in Bose et al.'s (2007) study.

Regression has been employed using an unbalanced panel of annual data from 1972 to 2012 for the sample of 75 countries listed in Table 2-1. The data has been taken from two main databases, namely Government Finance Statistics (GFS) for fiscal variables and World Development Indicators 2015 (WDI 2015) for dependent and other non-fiscal control variables. Additional information about the data used is included in Appendix 1.

To understand the permanent effects on growth from public expenditure in Study 1, we firstly use the following five static models for the analysis: a pooled regression; a cross-section fixed effects model; a cross-section random effects model; a two-way fixed effects model; and a two-way random effects model.

Model selection methods used for static models in Study 1 are the adjusted R^2 and the Hausman test. Using both tests shows that the two-way fixed effects model is preferred in most of the specifications. Therefore, the following analysis starts with the results of the two-way fixed effects model.

Growth regressions in previous studies have extensive sets of variables included on the right-hand side of the equation. This study mainly includes the variables used in the framework proposed by Bose et al. (2007), which featured three sets of variables: conditioning variables (I) for growth regression; indicators (Z) for monetary policies, trade policies and market distortion; and variables of particular interest for the study (M), mainly government expenditure. The advantage of using this classification is that the typical set of conditioning variables (I) are distinctly separated from the particular set of conditioning variables (Z) for the study on the relationship between public expenditure and economic growth. We can refer these variants to our base regression (I variables) and regression as a robustness check (Z variables). The following subsections include model specification, issues of endogeneity and non-linearity, and our regression results for both developing and high-income Sample 1 countries.

2.2.1 Model specification

We begin the analysis with the standard set of control variables in base regression. Secondly, the robustness check for base regression is required in

order to detect the sensitivity of the analysis. Thirdly, the government budget constraint is taken into account to avoid bias from the exclusion of important elements of fiscal variables. Lastly, we include government budget constraint together with variables for the robustness check. This final specification is expected to provide the most reliable estimates, since the biases from both omitted variables and the exclusion of government budget constraint are taken into account.

1.) Base regression

In our base regression, independent variables are separated into two sets which are: six conditioning variables (I); and variables of particular interest (M) on public spending. The growth regression is represented by Equation (1).

$$GR_{it} = \beta_{0t} + \sum_{j=1}^{6} \beta_j^I I_{j.it} + \beta^M M_{it} + u_{it} \quad (1)$$

There are several forms for the measurement of economic growth which could be used as the dependent variable. However, one of the most standardised forms is the growth of gross domestic product per capita in percentage terms (GR_{it}). The per capita growth rate is generally related to two different types of conditioning variables: the initial level of state variables and the other control (environmental) variables. Morozumi and Veiga (2016) argue that, while state variables describe the initial position of the economy, the control variables determine the steady-state level of output per effective worker. In our framework of the public-policy endogenous growth model, fiscal variables also have potential impacts on the steady-state per capita growth rate. Our conditioning variables (I) include both initial levels of state variables and the other environmental variables.

In the extensions of the neoclassical and endogenous growth models, Easterly and Rebelo (1993) claim that the rate of growth is a function of two types of state variables: the initial level of physical capital and the initial level of human capital. The stock of human capital can be represented in the forms of educational attainment and health, particularly in the model of Barro and Sala-i-Martin (2004). We therefore include initial GDP per capita, initial school enrolment rates and initial life expectancy as the proxies for state variables in

this study. Initial school enrolment rates and initial life expectancy represent initial levels of human capital.

We will firstly consider initial GDP per capita. A number of studies include initial GDP per capita as a state variable. The coefficient of the initial level of per capita GDP represents the rate of convergence; that is, the responsiveness of the growth rate to a proportional change in initial GDP per capita (Barro & Sala-i-Martin, 2004; Morozumi & Veiga, 2016). Barro and Lee (1994) argue that this state variable captures a conditional convergence effect, whereby a country grows faster if it begins at lower real per capita GDP relative to its initial level of human capital. This effect is predicted by neoclassical growth theory for the economy during the transition; however, its impact will not affect steady-state rate of growth (Kormendi & Meguire, 1985).

Most studies use the value of real GDP per capita of a year at the beginning of the period as initial GDP per capita (Barro, 1991; Easterly & Rebelo, 1993; Kneller et al, 1999; Levine & Renelt, 1992; Morozumi and Veiga, 2016). This variable might also appear in growth regression in the form of the log of initial GDP per capita (Bose et al, 2007) or lagged real per capita GDP (Miller and Russek, 1997). We use one-year lag of the log of GDP per capita as a proxy of initial GDP per capita.

Secondly, we look at initial school enrolment rates. Barro (1991) emphasised the important role played by human capital as a key driving force behind the research sector's generation of new products or ideas which underlie technological progress in a number of endogenous growth models. New goods are introduced to countries with greater initial stocks of human capital at a more rapid rate, ultimately leading to faster rates of growth. Nehru et al. (1995) also focus on the significant impact of human capital formation on the long-term growth of output, especially in developing countries.

The two main proxies for human capital in Barro (1991) are the 1960 values of school enrolment at secondary and primary levels. These are similar to the measures used by Levine and Renelt (1992), and Easterly and Rebelo (1993). Landau (1983) treated these school enrolment variables as investment in education by using the measures of enrolment ratios in primary and secondary schools, the percentage of 20 to 24-year-olds within the population enrolled in higher education, and a weighted sum of these three.

Alternatively, the measures of educational attainment are based on years of schooling (Barro & Sala-i-Martin, 2004; Morozumi & Veiga, 2016). Folster and Henrekson (2001) use growth rate of the average years of schooling as the growth of human capital

The initial school enrolment ratio in our study is a linear combination of primary, secondary and tertiary school enrolment ratios. This calculation is equivalent to Bose et al.'s (2007) methodology.

Thirdly, life expectancy represents the stock of human capital in the form of health in Barro and Sala-i-Martin (2004). The life expectancy variable in their study is the reciprocal of life expectancy at age one. These values would correspond to the mortality rate per year if mortality were independent of age.

In contrast, Barro and Lee (1994) measure life expectancy at birth by an average of values prevailing over the five years prior to the start of each decade. In our study, this variable enters the equation in the form of the log of life expectancy at birth (one-year lag).

In addition to these three state variables, we use investment, taxes and political instability as control variables in our base regression. We consider investment first. The effect of the saving rate in the neoclassical growth model is measured empirically by the ratio of real investment to real GDP (Barro & Sala-i-Martin, 2004).

The role of investment in the endogenous growth model is even more important, since an increase in capital stocks can raise the level of technology within the whole economy. This positive externality could finally enhance the steady-state rate of growth. Most literature (Barro & Lee, 1994; Folster & Henrekson, 2001; Kneller et al., 1999; Levine & Renelt, 1992; Miller & Russek, 1997; Morozumi & Veiga, 2016) includes an investment variable as a share of GDP as a control variable in growth regression.

Secondly, we look at the role of taxes. Cashin (1995) has claimed that previous empirical studies of the influence of fiscal policies on growth have predominantly concentrated on the effects of government consumption spending and have largely ignored the effects of distortionary taxes. The importance of considering these effects too is emphasised by Kocherlakota and Yi (1997) who found that the implications for exogenous growth are usually rejected when both a tax variable and a public capital variable are included in

the regression. Thus, failing to include both variables biases the results in favour of exogenous growth models.

Bose et al. (2007) claim that it is necessary to control tax revenue in order to assess fiscal-growth effects properly. The growth-enhancing effect of the provision of public goods is subjected to growth-diminishing effect of the distortionary taxes raised to fund the provision of the same public goods. Hence, tax revenue as a share of GDP is incorporated into our base regression.

Lastly, we consider political instability. Two measures of political instability have been used by Barro (1991). The first variable measures the number of revolutions and coups per year, which have also been measured by Levine and Renelt (1992). The second variable measures the number of assassinations per million population per year. These measures were interpreted as adverse influences on property rights, and thereby as negative influences on investment and growth.

The two measures can be combined as an index of political instability. Bose et al. (2007) calculate this by taking the average of revolutions and coups per year and political assassinations per million inhabitants in each decade.

Alternatively, Barro and Lee (1994) use the average number of successful and unsuccessful revolutions per year over the full sample, 1960-1985, representing the probability of revolution.

The calculation of our political instability index follows the definition used by Bose et al. (2007). The political instability index in our study is an average of revolutions and coups, and assassinations.

As a result, the set of control variables in base regression includes initial GDP per capita (ILGDPPAX1P), initial school enrolment (IPST1P), initial life expectancy (ILLIFE1P), gross capital formation as a share of GDP (K), tax revenue as a share of GDP (tax_gdp) and index of political instability (PINST). Table 2-4 shows the list of control variables.

Table 2-4: List of control variables for Study 1

Variables	Description of the variables
ILGDPPAX1P	Lag one year of log of GDP per capita (2005 USD)
IPST1P	Lag one year of a linear combination of school enrolment
ILLIFE1P	Lag one year of log of life expectancy
K	Gross capital formation (% of GDP)
tax_gdp	Tax revenue (% of GDP)
PINST	Average of successful coups and assassinations of executives

$$GR_{it} = \beta_{0t} + \beta_1 ILGDPPAX1P_{it} + \beta_2 IPST1P_{it} + \beta_3 ILLIFE1P_{it} + \beta_4 K_{it} + \beta_5 tax\_gdp_{it} + \beta_6 PINST_{it} + \beta^M M_{it} + u_{it} \quad (2)$$

Growth regression with these six control variables including a type of public spending by function (M) at each point in time is exhibited in Equation (2). The effect of each type of public spending on economic growth is then analysed accordingly.

The set of variables of interest (M) consists of government expenditure by function according to the data from International Monetary Fund's (IMF) Government Finance Statistics (GFS), both at aggregate and disaggregated levels. They are each measured as a fraction of GDP. For the aggregate level, we use a measure of total expenditure. At the disaggregated level, there are six variables included in our regression analysis, which are: general public services; defence; transportation and communication; education; health; and social welfare (see Table 2-5).

Table 2-5: List of variables for types of government expenditure (Study 1)

Variables	Description of the variables
tot_gdp	Total expenditure (% of GDP)
1. gps_gdp	Spending on general public services (% of GDP)
2. def_gdp	Spending on defence (% of GDP)
3. trc_gdp	Spending on transportation and communication (% of GDP)
4. edu_gdp	Spending on education (% of GDP)
5. hea_gdp	Spending on health (% of GDP)
6. soc_gdp	Spending on social welfare (% of GDP)

2.) Robustness check

In addition to the set of control variables included in a base regression, we can also measure the impacts of monetary and trade policies through the ratio of broad money and trade. These are Z variables in Bose et al. (2007).

First, we consider the ratio of broad money. Some might argue that a monetary aggregate captures not only the effect of monetary policy but also the development of a financial system.

The special role played by the domestic financial development has been stressed by King and Levine (1993) and Greenwood and Jovanovic (1990).

Barro and Sala-i-Martin (2004) consider two proxies for this financial development. One is the ratio of private financial system credit to GDP and the other is a measure of financial deposits (the M3 aggregate less the transactions-related M1 aggregate, as a ratio to GDP).

Similarly, Calderon and Liu (2003) employ two commonly used measures of financial development: the ratio of broad money (M2) to GDP and the ratio of credits provided by financial intermediaries to the private sector to GDP. The ratio of broad money (M2) to GDP is also used by Easterly and Rebelo (1993).

De Gregorio and Guidotti (1995) argue that credit has a clear advantage over measures of monetary aggregates in that it more accurately represents the actual volume of funds channelled into the private sector. According to De Gregorio and Guidotti's (1995) argument on sources of private funds, it is more appropriate in our analysis to describe the ratio of M2 to GDP as a proxy of monetary policy rather than to claim it as a proxy of financial development.

Secondly, we look at the role of trade. A measure of the extent of international openness is the ratio of exports plus imports to GDP (Barro & Sala-i-Martin, 2004; Easterly & Rebelo, 1993; Miller and Russek, 1997). Some studies may include trade variables as the ratio of exports to GDP or the ratio of imports to GDP separately.

Table 2-6: List of variables for the robustness check (Study 1)

Variables	**Description of the variables**
M2	Money and quasi money comprise the sum of currency outside of banks, demand deposits other than those of the central government, and the time, savings, and foreign currency deposits of resident sectors other than the central government. (% of GDP)
TRADE	The sum of exports and imports of goods and services (% of GDP)

In our study, the other two control variables (Z), which are M2 as a fraction of GDP and trade as a fraction of GDP, are added to the set of independent variables (I) (see Equation (3)). As discussed above, these two control variables are the proxies for monetary and trade policies. The descriptions of these variables are shown in Table 2-6. This specification is analysed as a robustness check.

$$GR_{it} = \beta_{0t} + \beta_1 ILGDPPAX\,1P_{it} + \beta_2 IPST1P_{it} + \beta_3 ILLIFE\,1P_{it} + \beta_4 K_{it} + \beta_5 tax\_gdp_{it} + \beta_6 PINST_{it} + \beta_7 M\,2_{it} + \beta_8 TRADE_{it} + \beta^M M_{it} + u_{it} \quad (3)$$

3.) Government budget constraint

Most previous studies of the association between government expenditure and growth are subject to potential biases because they omit variables that enter the government's budget constraint (Bose et al., 2007). The main elements in government budgets are revenue, expenditure, and budget balance. When incorporating government budget constraint into growth regression, however, one element of budget constraint must be omitted in order to avoid perfect multicollinearity. In other words, the regression equations need to include all but one of the possibilities for sources and uses of various revenues, various expenditures and the surplus (Miller & Russek, 1997). Hence, the coefficient on each fiscal variable is the effect of a unit change in the relevant variable offset by the effect of a unit change in the omitted fiscal variable, as explained by Kneller et al. (1999). The omitted variable should have negligible growth effects, which means that the omitted variable is supposed to have an insignificant or zero coefficient. Otherwise, the results will be biased because of the implicit partial financing by non-neutral elements of the government budget.

As in Bose et al.'s (2007) study, non-tax revenue is chosen as the implicit financing element. The coefficient of each remaining fiscal variable is the effect of a unit change in that relevant fiscal variable offset by the effect of a unit change in non-tax revenue as a share of GDP.

Budget surplus, i.e. the difference between government revenue and total public expenditure, must be added to the set of control variables in base regression. Rather than entering each type of spending into the equation separately, we must also include the other part of spending (other spending by function) in each of the equations as another control variable. The role of government budget constraint will be further explored in Chapter 3 by selecting different implicit financing elements.

The example of growth regression shown in Equation (4) below illustrates the impact of general public services spending (gps_gdp) on economic growth, including government budget constraint. The budget surplus

is represented as a ratio of overall budget surplus/deficit as a fraction of GDP. Spending outside of the general public services category is represented as its ratio to GDP (otgps_gdp).

Similarly, the specification in Equation (4) is also applied to defence, transportation and communication, education, health, and social welfare spending. The details of these variables are included in Table 2-7.

$$GR_{it} = \beta_{0t} + \beta_1 ILGDPPAX\ 1P_{it} + \beta_2 IPST\,1P_{it} + \beta_3 ILLIFE\,1P_{it} + \beta_4 K_{it} + \beta_5 tax\_gdp_{it} + \beta_6 PINST_{it} + \beta_7 SURBP_{it} + \beta_8 gps\_gdp_{it} + \beta_9 otgps\_gdp_{it} + u_{it} \quad (4)$$

Table 2-7: List of variables for government budget constraint (Study 1)

Variables	Description of the variables
SURBP	Budget surplus/deficit (% of GDP)
otgps_gdp	Public spending other than general public services spending (% of GDP)
otdef_gdp	Public spending other than defence spending (% of GDP)
ottrc_gdp	Public spending other than transportation and communication spending (% of GDP)
otedu_gdp	Public spending other than education spending (% of GDP)
othea_gdp	Public spending other than health spending (% of GDP)
otsoc_gdp	Public spending other than social welfare spending (% of GDP)

4.) Government budget constraint and robustness check

Finally, both the variables from government budget constraint and the robustness check are considered together with the control variables from the base regression. The example of growth regression shown in Equation (5) illustrates the impact of general public services spending (gps_gdp) on economic growth, including government budget constraint, monetary aggregate and trade policy. This specification is also employed with the functional spending of defence, transportation and communication, education, health, and social welfare.

$$GR_{it} = \beta_{0t} + \beta_1 ILGDPPAX\ 1P_{it} + \beta_2 IPST\,1P_{it} + \beta_3 ILLIFE\,1P_{it} + \beta_4 K_{it} + \beta_5 tax\_gdp_{it} + \beta_6 PINST_{it} + \beta_7 M2_{it} + \beta_8 TRADE_{it} + \beta_9 SURBP_{it} + \beta_{10} gps\_gdp_{it} + \beta_{11} otgps\_gdp_{it} + u_{it} \quad (5)$$

2.2.2 Endogeneity and non-linearity

In addition to four different model specifications we use for our fiscal-growth studies with classical estimates (two-way fixed effects model), the potential endogeneity of some control variables and possible non-linear relationship between growth and public spending are also investigated. This verification involves some misspecification tests (the Durbin-Wu-Hausman test and the RESET test).

1.) Endogeneity

Linking public spending with growth requires the use of control variables, and therefore an underlying endogeneity issue may arise from the problems of simultaneity and reverse causality.

In our set of aforementioned control variables, tax revenue and investment are susceptible to this endogeneity problem, as discussed in Chapter 1. With such a problem, ordinary least squares method will not yield consistent estimates.

Using the Durbin-Wu-Hausman test, we can confirm that our two-way fixed effects model for four different specifications is subject to an endogeneity problem. We then use instrumental estimates - namely two-stage least squares (2SLS) - to take the endogeneity problem into account. One-year lag variables are instruments for both tax revenue and investment.

2.) Non-linearity

A potential non-linear relationship between growth and public spending has been shown by Barro (1990): growth rate increases with public spending when a government is small, but declines if a government becomes large.

Since Ramsey's RESET test has detected the non-linearity for the relationship between public spending and economic growth, we include the quadratic term of public spending to capture this non-linear impact, both at aggregated and disaggregated level.

2.2.3 Regression results

We are interested in investigating the different permanent growth impacts of various types of public spending between developing and high-income countries, using cross-section and time series data. By separately analysing the set of results for developing and high-income Sample 1 countries, heterogeneity bias in the panel data is partially controlled. Since the estimation of the two-way fixed effects model contains an endogeneity problem, we mainly report the results with instrumental estimates using two-stage least squares (2SLS). In addition, the potential non-linear relationship between public spending and growth is examined by using the square term of public spending.

In each of the following tables (Table 2-8 to 2-11), we report the results of a particular type of public spending with six different model specifications. The first specification is the two-way fixed effects model of base regression. The second to the fifth specifications are instrumental estimates with year and country fixed effects of base regression, regression for the robustness check, regression with government budget constraint, and regression with government budget constraint and a robustness check. In the sixth specification, the square term of public spending as a share of GDP is added to the equation of the fifth specification in order to identify any non-linear relationship between public spending and economic growth.

Particular attention should be paid to the fifth and the sixth specifications, since the biases of the estimates and the endogeneity problem have been dealt with.

Based on the fact that transportation and communication is the only type of functional spending that has a statistically significant positive relationship with growth, our discussion then focusses only on the role of total spending and transportation and communication spending in determining economic growth for developing and high-income Sample 1 countries. The reasons for positive growth impacts of telecommunication investment are explained by Roller and Waverman (2001). This will be further discussed and analysed in Section 4.1 of Chapter 4.

1.) Developing Sample 1 countries

We firstly discuss the effects of total spending on economic growth in developing countries. As can be seen from Table 2-8, the impact of an increase in total spending on economic growth is sensitive to the set of control variables. Nonetheless, the positive growth effect of additional spending exists once government budget constraint has been taken into account. The instrumental estimate in Column (5) of Table 2-8 shows that a one percentage to GDP increase in public spending raises per capita GDP growth by 0.14%. However, the net growth effects of an increase in public spending would become negative from the adverse impact of raising tax revenue as a source of funds for additional spending.

In Column (6) of Table 2-8, the non-linear specification suggests that the net negative effects of public spending on growth presented in Column (5) can be reversed by the positive coefficient of the square term of total spending when the size of total spending is large enough. This can be referred to in cases where developing countries might underspend government expenditure. Therefore, the positive effect of fiscal policy has not yet been achieved at high level of public spending.

In terms of the effects of state variables, a developing country with a high initial GDP per capita will experience low per capita growth. A one percentage increase in initial GDP per capita implies a 0.06% to 0.07% decrease in per capita GDP growth. This evidence supports the conditional convergence hypothesis.

For initial human capital, initial school enrolment rate has insignificant relationship with growth while higher initial life expectancy has a favourable impact on economic development. Per capita GDP growth of developing Sample 1 countries could increase by as much as 0.13% as a result of a 1% rise in life expectancy.

The OLS estimates in Column (1) of Table 2-8 suggest that a 1% of GDP increase in investment can be converted to the increment of 0.23% per capita growth. Instrumental estimates have shown that this positive outcome is overstated. In fact, the increase might be less than 0.10%.

Table 2-8: Growth regressions with total public spending of developing Sample 1 countries (1972-2012)

Estimation method	OLS	2SLS	2SLS	2SLS	2SLS	2SLS
Dependent variable	GR	GR	GR	GR	GR	GR
Endogenous variable		tax_gdp K	tax_gdp K	tax_gdp K	tax_gdp K	tax_gdp K
	(1)	**(2)**	**(3)**	**(4)**	**(5)**	**(6)**
Regressor	**b/se**	**b/se**	**b/se**	**b/se**	**b/se**	**b/se**
Initial GDP per capita	-6.9673***	-6.2327***	-6.2231***	-7.1247***	-6.9561***	-6.7273***
	(1.06)	*(1.11)*	*(1.22)*	*(1.14)*	*(1.25)*	*(1.25)*
Initial school enrolment	-0.0100	-0.0215	-0.0228	-0.0407	-0.0365	-0.0270
	(0.05)	*(0.05)*	*(0.05)*	*(0.05)*	*(0.05)*	*(0.05)*
Initial life expectancy	-0.6912	6.2828	10.9079**	10.2104**	13.4883***	13.1456***
	(4.44)	*(4.87)*	*(4.96)*	*(4.83)*	*(4.88)*	*(4.88)*
Gross capital formation (% of GDP)	0.2261***	0.0876**	0.0699*	0.0471	0.0406	0.0373
	(0.03)	*(0.04)*	*(0.04)*	*(0.04)*	*(0.04)*	*(0.04)*
Taxes (% of GDP)	-0.0588	-0.0757	-0.0566	-0.2126***	-0.3021***	-0.2794***
	(0.05)	*(0.07)*	*(0.08)*	*(0.08)*	*(0.10)*	*(0.10)*
Political instability	-3.3267*	-3.4360*	-3.5224*	-3.5453*	-3.6392*	-3.6926**
	(1.92)	*(1.91)*	*(1.89)*	*(1.89)*	*(1.87)*	*(1.87)*
M2 (% of GDP)			-0.0467***		-0.0325**	-0.0363**
			(0.02)		*(0.02)*	*(0.02)*
Trade (% of GDP)			0.0476***		0.0431***	0.0396***
			(0.01)		*(0.01)*	*(0.01)*
Budget surplus (% of GDP)				0.3349***	0.3965***	0.4207***
				(0.06)	*(0.07)*	*(0.07)*
Total spending (% of GDP)	-0.0990***	-0.0851***	-0.0866**	0.0895*	0.1386**	-0.0140
	(0.03)	*(0.03)*	*(0.03)*	*(0.05)*	*(0.06)*	*(0.09)*
Square term of total spending (% of GDP)						0.0022**
						(0.00)
Number of observations	910	879	870	872	863	863

Notes: Standard errors in parentheses below parameters

***, **, * Statistical significance at 1%, 5% and 10% respectively

As expected, an increase in tax revenue deteriorates growth, since it distorts investment decisions and can also be a disincentive to labour. The negative growth effect of additional taxes is large when taking government budget constraint into account. This can be interpreted as showing that the detrimental effect is exacerbated when a government's resources are relatively limited.

Political instability is conceivably a factor that undermines economic growth, particularly in developing Sample 1 countries through coups or political assassinations. The coefficients for political instability are negatively significant.

An increase in the ratio of monetary aggregates to GDP has an adverse impact on growth. In this case, it can be argued that M2 as a percentage of GDP might not be a legitimate proxy for financial sophistication in developing Sample 1 countries. In fact, national government uses money creation as a way to monetise its debt in order to pay for budget deficits. In this process, debt issued by the government is purchased by created money from the central bank. This can lead to hyperinflation, particularly when such transactions are carried out unaccountably and excessively. As a result of this hidden tax, consumers then lose purchasing power. Therefore, debt monetisation could have a growth-deterring impact.

As one might expect, the growth effect of trade openness is favourable. However, the impact might be less than we would have expected. An increase of one percent of GDP in trade ratio can boost per capita GDP growth of developing Sample 1 countries by 0.04% to 0.05%.

The improvement of budget balance has a positive effect on economic growth. This reflects the importance of fiscal health and the fiscal responsibility of a government in determining economic development in developing Sample 1 countries.

The impact of an increase in transportation and communication spending on economic growth for developing Sample 1 countries is presented in Table 2-9. As with total spending, an increase in transportation and communication spending is positively and significantly related to economic growth, especially when government budget constraint is inclusively considered. The instrumental estimate in Column (5) of Table 2-9 shows that a 1% of GDP increase in transportation and communication spending can raise per capita growth rate by 0.67%.

Subsidising the increase of the spending by reducing other types of spending, the net positive effect of transportation and communication on economic growth is partially reduced. The non-linear estimation in Column (6) of Table 2-9 has shown that the partial relationship between transportation and communication spending and per capita GDP growth is concave.

The concavity suggests that the positive impact of transportation and communication spending on economic growth is somewhat restrained. Our results have shown that any increment increase of transportation and

communication spending while its level is above 8% of GDP will have opposing effect on growth in developing Sample 1 countries.

Table 2-9: Growth regressions with transportation and communication spending of developing Sample 1 countries (1972-2012)

Estimation method	OLS	2SLS	2SLS	2SLS	2SLS	2SLS
Dependent variable	GR	GR	GR	GR	GR	GR
Endogenous variable		tax_gdp K	tax_gdp K	tax_gdp K	tax_gdp K	tax_gdp K
	(1)	**(2)**	**(3)**	**(4)**	**(5)**	**(6)**
Regressor	**b/se**	**b/se**	**b/se**	**b/se**	**b/se**	**b/se**
Initial GDP per capita	-7.9854***	-7.3516***	-6.8430***	-8.1701***	-7.5718***	-7.8365***
	(1.11)	*(1.16)*	*(1.29)*	*(1.19)*	*(1.31)*	*(1.34)*
Initial school enrolment	-0.0225	-0.0183	-0.0150	-0.0200	-0.0125	-0.0001
	(0.05)	*(0.05)*	*(0.05)*	*(0.05)*	*(0.05)*	*(0.05)*
Initial life expectancy	-6.9163	0.2193	4.2903	4.6440	8.1199	10.0176*
	(4.70)	*(5.12)*	*(5.17)*	*(5.09)*	*(5.16)*	*(5.27)*
Gross capital formation (% of GDP)	0.2249***	0.0910**	0.0760**	0.0467	0.0408	0.0226
	(0.03)	*(0.04)*	*(0.04)*	*(0.04)*	*(0.04)*	*(0.04)*
Taxes (% of GDP)	-0.1599***	-0.1689***	-0.1436**	-0.2189***	-0.2895***	-0.3044***
	(0.05)	*(0.06)*	*(0.07)*	*(0.08)*	*(0.10)*	*(0.10)*
Political instability	-2.5557	-2.7249	-2.9376	-2.8973	-3.1152	-3.0671
	(2.09)	*(2.08)*	*(2.06)*	*(2.04)*	*(2.02)*	*(2.03)*
M2 (% of GDP)			-0.0533***		-0.0388**	-0.0394**
			(0.02)		*(0.02)*	*(0.02)*
Trade (% of GDP)			0.0395***		0.0380***	0.0368***
			(0.01)		*(0.01)*	*(0.01)*
Budget surplus (% of GDP)				0.3682***	0.4199***	0.4216***
				(0.06)	*(0.07)*	*(0.07)*
Transportation and communication spending (% of GDP)	0.1246	0.0453	0.1139	0.6169***	0.6669***	1.1504***
	(0.17)	*(0.17)*	*(0.17)*	*(0.19)*	*(0.19)*	*(0.40)*
Other spending (% of GDP)				0.0751	0.1171**	-0.1406
				(0.05)	*(0.06)*	*(0.06)*
Square term of transportation and communication spending (% of GDP)						-0.0688
						(0.04)
Square term of other spending (% of GDP)						0.0042**
						(0.00)
Number of observations	850	823	814	816	807	807

Notes: Standard errors in parentheses below parameters

***, **, * Statistical significance at 1%, 5% and 10% respectively

The effects of control variables on growth in the regressions with transportation and communication spending of developing Sample 1 countries are relatively similar to growth regressions with total spending. The only difference is that the coefficients of initial life expectancy and political instability have become insignificant, although they are still positive and negative respectively.

The results for growth regression with other types of functional spending in developing Sample 1 countries can be found in Appendix 2. The increases in these spending types have either insignificant or negative significant relationships with growth. With linear specifications, the increases in general public services, defence and health spending have insignificant effects on per capita GDP growth, whereas rises in education and social welfare spending have growth-diminishing effects.

2.) High-income Sample 1 countries

The estimates in Table 2-10 illustrate the effects of increases in total spending on per capita GDP growth of high-income Sample 1 countries.

An increase in total public spending in high-income Sample 1 countries has a negative impact on per capita GDP growth, except in the growth regression which includes both government budget constraint and the robustness check in Column (5), where its coefficient is insignificant. The coefficient of the square term of total spending in the non-linear specification is positive and significant, suggesting that an increase in total spending when its level has already been exceptionally high could promote growth. In order to raise total spending, the main source of funds will be tax collection, which has a growth-deteriorating effect, although the coefficient of taxes is insignificant. As a result, the level of total spending in the range that needs to be matched seems to be unattainable.

The effects of state variables on per capita GDP growth of high-income Sample 1 countries are similar to that of developing Sample 1 countries. A 1% increase of initial GDP per capita leads to a decline of per capita growth by 0.05% to 0.07%. Initial school enrolment rate is not significantly linked with per capita GDP growth, whereas an increase in initial life expectancy is growth-

promoting. A 1% rise in life expectancy may increase per capita GDP growth by up to 0.23%.

Table 2-10: Growth regressions with total public spending of high-income Sample 1 countries (1972-2012)

Estimation method	OLS	2SLS	2SLS	2SLS	2SLS	2SLS
Dependent variable	GR	GR	GR	GR	GR	GR
Endogenous variable		tax_gdp K	tax_gdp K	tax_gdp K	tax_gdp K	tax_gdp K
	(1)	**(2)**	**(3)**	**(4)**	**(5)**	**(6)**
Regressor	**b/se**	**b/se**	**b/se**	**b/se**	**b/se**	**b/se**
Initial GDP per capita	-7.1485***	-5.2028***	-4.9127***	-5.2676***	-5.2940***	-5.0356***
	(0.77)	*(0.87)*	*(0.96)*	*(0.90)*	*(0.99)*	*(1.00)*
Initial school enrolment	0.0488***	0.0262	0.0220	0.0251	0.0153	0.0191
	(0.02)	*(0.02)*	*(0.02)*	*(0.02)*	*(0.02)*	*(0.02)*
Initial life expectancy	6.8907	21.3283**	21.0727**	21.6753***	23.2569***	21.7850**
	(7.36)	*(8.30)*	*(8.76)*	*(8.35)*	*(8.82)*	*(8.87)*
Gross capital formation (% of GDP)	0.3699***	0.0289	0.0377	0.0301	0.0458	0.0308
	(0.03)	*(0.04)*	*(0.05)*	*(0.04)*	*(0.05)*	*(0.05)*
Taxes (% of GDP)	-0.0231	0.0460	0.0104	0.0304	-0.0821	-0.1281
	(0.04)	*(0.06)*	*(0.07)*	*(0.09)*	*(0.10)*	*(0.11)*
Political instability	1.8894	1.9113	2.4215	1.9764	2.8326	3.2460
	(2.33)	*(2.47)*	*(2.50)*	*(2.48)*	*(2.50)*	*(2.52)*
M2 (% of GDP)			-0.0124***		-0.0135***	-0.0150***
			(0.00)		*(0.00)*	*(0.00)*
Trade (% of GDP)			0.0271***		0.0281***	0.0234***
			(0.01)		*(0.01)*	*(0.01)*
Budget surplus (% of GDP)				0.0190	0.1085*	0.1213*
				(0.06)	*(0.07)*	*(0.07)*
Total spending (% of GDP)	-0.0845***	-0.1487***	-0.1275***	-0.1373***	-0.0614	-0.2043**
	(0.02)	*(0.03)*	*(0.03)*	*(0.05)*	*(0.06)*	*(0.08)*
Square term of total spending (% of GDP)						0.0017**
						(0.00)
Number of observations	1115	1097	920	1097	920	920

Notes: Standard errors in parentheses below parameters

***, **, * Statistical significance at 1%, 5% and 10% respectively

The coefficients of gross capital formation are positive but insignificant. Neither taxes nor political instability are significantly related to per capita GDP growth.

The robustness check confirms a growth-enhancing effect of trade openness which is lower than that of developing Sample 1 countries. However, an increase in M2 as a percentage of GDP has a detrimental effect on growth. High M2 as a percentage of GDP reflects a tendency for the government to engage in inflation financing. This is a relatively inefficient form of taxation.

Budget surplus may also have a positive relationship with economic growth, even though the effects might not be as trivial as they are in developing Sample 1 countries.

The effects of an increase in transportation and communication spending on growth in high-income Sample 1 countries are considered by using the estimates from Table 2-11. A 1% of GDP increase in transportation and communication spending raises per capita growth rate by 1.2%, as can be seen from the specification in Column (5).

The non-linear specification has demonstrated that the partial relationship between transportation and communication spending and growth in high-income Sample 1 countries is also concave. The positive growth impact of additional transportation and communication spending within high-income Sample 1 countries might only be attained when the level of spending is below 4% of GDP.

The impacts of other control variables on growth are congruent with those of estimates with total public spending. Therefore, these variables in Table 2-11 are not discussed.

In contrast to transportation and communication spending, increases in spending on general public services, education and social welfare have a deteriorating impact on growth with linear specifications. Spending on defence and health is not significantly related to per capita GDP growth. The results for growth regression with all these types of functional spending of high-income Sample 1 countries are included in Appendix 2.

Table 2-11: Growth regressions with transportation and communication spending of high-income Sample 1 countries (1972-2012)

Estimation method	OLS	2SLS	2SLS	2SLS	2SLS	2SLS
Dependent variable	GR	GR	GR	GR	GR	GR
Endogenous variable		tax_gdp K	tax_gdp K	tax_gdp K	tax_gdp K	tax_gdp K
	(1)	**(2)**	**(3)**	**(4)**	**(5)**	**(6)**
Regressor	**b/se**	**b/se**	**b/se**	**b/se**	**b/se**	**b/se**
Initial GDP per capita	-7.2272***	-5.3636***	-6.4640***	-5.0866***	-6.5818***	-6.5007***
	(0.81)	*(0.90)*	*(1.04)*	*(0.91)*	*(1.07)*	*(1.08)*
Initial school enrolment	0.0317*	-0.0007	0.0093	0.0193	0.0315	0.0331
	(0.02)	*(0.02)*	*(0.02)*	*(0.02)*	*(0.02)*	*(0.02)*
Initial life expectancy	12.9068*	28.0563***	31.0129***	25.0199***	27.7952***	25.9299***
	(7.76)	*(8.48)*	*(9.16)*	*(8.30)*	*(9.00)*	*(8.99)*
Gross capital formation (% of GDP)	0.3866***	0.0471	0.0442	0.0061	-0.0029	-0.0030
	(0.03)	*(0.04)*	*(0.05)*	*(0.05)*	*(0.05)*	*(0.05)*
Taxes (% of GDP)	-0.0726**	-0.1146**	-0.1437***	0.0103	-0.1253	-0.1516
	(0.04)	*(0.05)*	*(0.06)*	*(0.09)*	*(0.11)*	*(0.11)*
Political instability	1.9546	2.2064	2.7876	2.6683	3.4355	3.8010
	(2.33)	*(2.47)*	*(2.58)*	*(2.42)*	*(2.52)*	*(2.52)*
M2 (% of GDP)			-0.0151***		-0.0099**	-0.0109**
			(0.00)		*(0.00)*	*(0.00)*
Trade (% of GDP)			0.0291***		0.0238***	0.0217**
			(0.01)		*(0.01)*	*(0.01)*
Budget surplus (% of GDP)				0.0630	0.1589**	0.1660**
				(0.06)	*(0.07)*	*(0.07)*
Transportation and communication spending (% of GDP)	0.0480	0.0819	0.8324***	0.1222	1.2017***	2.2411***
	(0.11)	*(0.12)*	*(0.23)*	*(0.13)*	*(0.26)*	*(0.65)*
Other spending (% of GDP)				-0.1227**	-0.0640	-0.2003**
				(0.05)	*(0.06)*	*(0.06)*
Square term of transportation and communication spending (% of GDP)						-0.3210*
						(0.17)
Square term of other spending (% of GDP)						0.0017**
						(0.00)
Number of observations	1073	1057	893	1048	884	884

Notes: Standard errors in parentheses below parameters

***, **, * Statistical significance at 1%, 5% and 10% respectively

2.2.4 Comparison of Study 1 with previous results

Our fiscal-growth studies estimates can be compared to those in earlier literature. The results for developing Sample 1 countries will be primarily compared with those obtained by Bose et al. (2007). We should note that the two studies draw data from different time periods. While Bose et al. (2007) use decade averages over the 1970s and 1980s, our study uses annual data from 1972 to 2012. Where possible, the estimates for high-income Sample 1 countries are also discussed. The effects of both public spending variables and control variables on economic growth are evaluated respectively.

1.) Public spending

The effects of an increase in total public spending on economic growth are mostly found to be growth-diminishing in cross-country studies. The studies of Lin (1994), and Jiranyakul and Brahmasrene (2007) are some of the exceptions in which a growth-enhancing effect from additional government expenditure was found. Most studies using samples of high-income countries find negative impacts of increased total spending on growth (Bergh & Karlsson, 2010; Folster & Henrekson, 2001; Romero-Avila & Strauch, 2008), whereas the growth impacts from increased spending of developing countries are not unanimous.

Our results for high-income Sample 1 countries with adverse effects on growth from an increase in total public spending are comparable to those in the majority of previous studies. The analysis of developing Sample 1 countries confirms the sensitivity of the results.

Unlike Bayraktar and Moreno-Dodson (2012), and Christie (2014), who found that the non-linear term of public spending is insignificantly related to growth, we found the coefficients of the square term of total spending to be positive and significant for both developing and high-income Sample 1 countries.

In Bose et al. (2007), in terms of public spending by function, education, transportation and communication, and defence spending have positive significant relationships with economic growth in base regression and regression for the robustness check. Interestingly, the results change

dramatically when the government budget constraint is taken into account, with education being the only spending type positively related to growth. In our study, only transportation and communication spending promotes growth, as can be seen in Table 2-12. This significant change of the estimates has underlined the bias of estimates where the role of government budget constraint is neglected. We can further compare the effects of each spending type by function in our study to those in other literature.

Table 2-12: Comparison between the results of Bose et al.'s (2007) study and our Study 1 (expenditure variables)

Expenditure/ studies	Bose et al. (2007)	Our study
Base regression		
Education	Positively significant	Negatively significant
Transportation and communication	Positively significant	Insignificant
Defence	Positively significant	Insignificant
Robustness check		
Education	Positively significant	Negatively significant
Transportation and communication	Positively significant	Insignificant
Defence	Positively significant	Insignificant
Government budget constraint		
Education	Positively significant	Negatively significant
Transportation and communication	Insignificant	Positively significant
Defence	Insignificant	Insignificant

The growth-enhancing effect of transportation and communication spending found in our study is consistent with that found in pre-existing studies (Aschauer, 1989; Easterly & Rebelo, 1993; Nurudeen & Usman, 2010). Our results earn further merits in detecting the concave relationship between transportation and communication spending and per capita GDP growth in Sample 1 countries. Specifically, developing Sample 1 countries may use transportation and communication spending to promote growth to a greater extent than high-income Sample 1 countries did. This highlights the role played by government spending in providing public infrastructure, especially for a country at the initial stages of development.

Education spending is mostly found to be insignificantly or positively related to economic growth in preceding research. Although the positive growth impact of education spending in our study is not found in linear regression, non-linear specification for developing Sample 1 countries has shown education spending to have a favourable growth effect at the level of spending below 4% of GDP. A few studies (Kelly, 1997; Nurudeen & Usman, 2010) show contradicting results with regard to adverse growth impacts of increased education spending. Interestingly, the partial non-linear relationship between education spending and growth in high-income Sample 1 countrires is convex. This might not provide the counter-argument towards the growth-promoting effect of education spending in high-income countries. It does, perhaps, suggest that these high-income Sample 1 countries spend on education efficiently, by mainly using either private funds or public spending. This could also be related to economies of scale in spending on education.

While most studies argue that increased defence spending has a negative effect on economic growth (Abdullah et al, 2009; Deger & Smith, 1983; Knight et al., 1996), some literature has found a positive (Benoit, 1978) or neutral growth impact (Barro & Sala-i-Martin, 2004; Biswas & Ram, 1986). Fredriksen and Looney (1982) illustrated that the growth impact of additional spending on defence depends on resource constraint. Countries which are relatively resource-constrained experience a growth-diminishing impact of an increase in defence spending, whereas a positive growth effect is otherwise found. Hence, the insignificant growth effect of increased defence spending in our developing and high-income Sample 1 countries can be appropriately explained by Fredriksen and Looney's argument. Since each group of countries in our study may include both countries with and without resource constraint in relative terms, growth impact from increased spending in defence is not detected.

Health spending is generally expected to have a positive relationship with economic growth (Abdullah et al, 2009; Nketia-Amponsah, 2009; Nurudeen & Usman, 2010). However, Kelly (1997) found a negative growth effect of increased health spending. Our estimates exhibit an insignificant relationship between health expenditure and the economic growth of developing and high-income Sample 1 countries.

Although Kelly (1997) has found that an increase in social welfare spending is growth-conducive, our analysis reveals opposite results. In recent decades, social welfare spending has increased dramatically due to population ageing. Recent data should be able to detect a negative growth effect of increased social welfare spending rather than a positive one.

The effects of general public services spending on growth are hardly mentioned in fiscal-growth studies. In our study, the growth impact of additional general public services spending is negative for high-income Sample 1 countries. This relationship is insignificant for developing Sample 1 countries.

2.) Control variables

The effects of control variables in our fiscal-growth studies can also be compared to those reported in earlier studies, including Bose et al. (2007). This comparison is illustrated in Table 2-13.

The state variables in our model specification include initial GDP per capita, initial school enrolment rate and initial life expectancy. Most studies confirm the conditional convergence hypothesis with negative coefficient for initial GDP per capita (Barro, 1991; Barro & Lee, 1994; Folster & Henrekson, 2001; Kneller et al., 1999; Miller & Russek, 1997; Morozumi & Veiga, 2016). Our estimates for both developing and high-income Sample 1 countries also provide consistent evidence in comparison with previous studies.

The relationship between initial school enrolment ratio and growth is predominantly found to be insignificant (Barro & Lee, 1994; Gemmell, 1996; Morozumi & Veiga, 2016; Pritchett, 2001) apart from in Barro (1991) and Benhabib and Spiegel (1994) where positive relationships were found. Our results conform to those in the majority of studies.

While Bose et al. (2007) failed to detect a growth-enhancing effect of an increase in initial life expectancy in their sample of developing countries, our study has found a positive relationship between initial life expectancy and per capita growth which is similar to that found in Barro and Lee (1994), and Barro and Sala-i-Martin (2004).

Hence, the growth-promoting effect of initial human capital in the endogenous growth model is exhibited in our study only through initial life expectancy.

Table 2-13: Comparison between the results of Bose et al.'s (2007) study and our Study 1 (control variables)

Control variables/ studies	Bose et al. (2007)	Our study
State variables		
Initial GDP per capita	Insignificant	Negatively significant
Initial school enrolment	Negative (some significance)	Insignificant
Initial life expectancy	Insignificant	Positive (some significance)
Other control variables		
Investment	Positively significant	Positive (some significance)
Taxes	Insignificant	Negatively significant
Political instability	Insignificant	Negative (some significance)
Robustness check		
M2	Insignificant	Negatively significant
TRADE	Insignificant	Positively significant
Government budget constraint		
Budget surplus	Positively significant	Positively significant

The other control variables in our base regression are investment, taxes and political instability. Vast amount of studies, including Bose et al. (2007), have found a positive relationship between investment and growth. When controlling for endogeneity, the positive effect of investment on growth in developing Sample 1 countries in our study is significantly reduced. For this reason, some preceding studies might have overstated the favourable growth effect of investment. The relationship between investment and growth in high-income Sample 1 countries is insignificant, as in the findings of Kneller et al. (1999).

Increased tax revenue mostly has a detrimental effect on growth. Distortionary taxation (Abdullah et al, 2009; Cashin, 1995; Kneller et al., 1999) and direct taxation (Romero-Avila & Strauch, 2008) are usually presented as

proxies for government revenue. We find a negative growth impact for additional taxes, especially in developing Sample 1 countries.

The results of Barro (1991) and Barro and Lee (1994) show the growth-retarding effect of an increase in political instability. The estimates for developing Sample 1 countries are consistent with previous studies, whereas the coefficients of political instability are insignificant for high-income Sample 1 countries.

The effects of monetary policy and trade are also examined in the regression for the robustness check.

Barro and Sala-i-Martin (2004) found that an increase in monetary aggregates has an insignificant relationship with economic growth. This finding is in agreement with that of Bose et al (2007). However, Calderon and Liu (2003) use both the ratios of monetary aggregates and credits to GDP to represent financial development. They find that financial development has a favourable growth impact. The results from our study have demonstrated detrimental growth effects from increased M2 as a percentage of GDP. We argue that the ratio of monetary aggregates to GDP in developing Sample 1 countries may instead reveal the growth impact from monetisation of government debt. The adverse effect in high-income Sample 1 countries might be influenced by the fact that countries with high levels of M2 as percentages of GDP are the ones with low per capita GDP growth.

An increase in trade openness could be growth-promoting. It increases opportunities for countries to better utilise their comparative advantages. Our results are in agreement with Barro and Sala-i-Martin's (2004). In contrast, the coefficients of trade ratio in Miller and Russek (1997) and Romero-Avila and Strauch (2008) are found to be insignificant.

Budget surplus has been shown to have a favourable growth effect (Easterly & Rebelo, 1993; Kneller et al., 1999; Miller & Russek, 1997). This positive effect can also be established for both developing and high-income Sample 1 countries in our study. This confirms the important role played by fiscal responsibility in determining economic growth.

2.3 Concluding remarks

When comparing public expenditure as a ratio of GDP between 1972 and 2012, the figures have shown that, on average, the size of government in high-income Sample 1 countries (34.82%) is greater than in developing Sample 1 countries (26.63%). This is mainly driven by the high levels of social welfare and healthcare spending in high-income Sample 1 countries. From the composition of public spending in the past four decades, it has been shown that social welfare spending as a share of total spending has increased significantly in developing Sample 1 countries while remaining high in high-income Sample 1 countries. In contrast, defence spending, and transportation and communication spending are decreasing over time, both as percentage of GDP and as a ratio of total spending. The proportion of education spending as share of total expenditure in developing Sample 1 countries (12.96%) is higher than in high-income Sample 1 countries (9.07%). Population aging is a global trend which will continue to be an important factor determining the level and allocation of government spending, especially with regard to potentially high levels of social welfare and health spending, for the next decade. This problem could become another obstacle for any developing country which tries to escape from the middle-income trap, since it becomes more challenging to channel sufficient public spending for productive use.

Under the framework used by Bose et al. (2007), our disaggregated analysis of the relationship between public expenditure and economic growth for groups of Sample 1 countries with different income levels also takes into account the problem of endogeneity from taxes and investment, and the potential non-linear relationship between public spending and economic growth. As with previous studies, the estimates confirm the growth-diminishing effect of an increase in public spending in high-income Sample 1 countries. The non-linear specification has shown that some developing Sample 1 countries' governments may be underspending on public expenditure provided that the square term of their country's total spending has a positive significant coefficient.

Transportation and communication is the only type of spending for which an increase has a favourable growth impact in both developing and high-income

Sample 1 countries using linear regression. With non-linear specification, the partial relationship between this type of spending and economic growth is concave. This suggests that the growth-promoting impact of transport and communication spending can be attained up to certain level of spending as a share of GDP. Developing countries may have more room to manoeuvre than high-income countries. Our results have shown that an increase in transportation and communication can be growth-enhancing up to the level of spending of 8% of GDP in developing Sample 1 countries and 4% of GDP in high-income Sample 1 countries. In our study, other types of spending have either insignificant or negative relationships with economic growth.

The relationship between control variables and economic growth in our study is principally consistent with previous studies. In terms of state variables, the evidence of conditional convergence hypothesis is prevalent. Although the school enrolment ratios are not significantly related to per capita GDP growth, initial life expectancy has a positive significant coefficient, especially for the estimates of high-income Sample 1 countries.

Without controlling for endogeneity, the positive growth impact of increased investment shown in prior studies might have been overestimated. An increase in tax revenue produces a growth-declining impact, especially for developing Sample 1 countries. Political instability can have a negative impact on growth in developing Sample 1 countries. While an increase in the trade ratio is growth-promoting, additional monetary aggregates can be harmful to growth. The underlying reason can be that a significant proportion of government debt is monetised. The positive association between budget surplus and growth reveals the externalities from government's financial responsibility.

To conclude, governments must take into account the increasing importance of social welfare and healthcare spending over time, especially in developing countries. They need to find the appropriate way in which to finance welfare spending; either by decreasing other types of expenditure or by raising additional revenue. Moreover, a disaggregated analysis of public expenditure and growth suggests the importance of the role played by increased transportation and communication spending in enhancing economic growth. This emphasises the significance of additional public infrastructure investment - something that governments need to be responsible for. It should also be noted

that the relationship between public spending and growth might be non-linear. As a result, the dynamism of fiscal policies is also required. Lastly, budget balance is the factor that not only represents a national government's fiscal position but also indicates better potential for growth in implementing fiscal policy.

Chapter 3: Public expenditure and economic growth: government budget constraint and long-run relationship

The previous chapter focusses on the disaggregated analysis of public spending and economic growth. In this chapter, we investigate the permanent growth effects of fiscal policy discussed in Section 3.1 by specifically considering the role that government budget constraint plays in different implicit financing elements. This will be referred to as Study 2. The data for this analysis comes from the sample group of 66 countries that can be seen in Table 3-1. This group will be referred to as Sample 2. The full set of Sample 2 countries comprises 34 developing countries and 32 high-income OECD countries.

In section 3.2, the relationship between public spending and long-run GDP per capita is investigated. While the studies featured in Chapter 2 and Section 3.1 of Chapter 3 put emphasis on the fiscal-growth relationship in the public-policy endogenous growth model, the analysis in Section 3.2 allows for Solow-type transitional dynamics where the effects of fiscal policy can be persistent. In this study, long-run and short-run effects of fiscal changes are identified separately. The study featured in Section 3.2 will be referred to as Study 3. This analysis uses the groups of smaller numbers of countries due to data availability. This group comprises 38 countries (17 developing countries and 21 high-income OECD countries), as shown in Table 3-7. These sample groups will be referred to as Sample 3. This section also includes a review of more recent studies, which is different from the strand of literature used for the analyses in Chapter 2 and Section 3.1 of Chapter 3.

In the next section, we consider the permanent growth effects of fiscal changes using broad categories of government revenue and government expenditure for the developing Sample 2 countries and high-income OECD Sample 2 countries, while also taking government budget into account.

Table 3-1: List of 66 Sample 2 countries (Study 2)

	Country	Income group		Country	Income group		Country	Income group		Country	Income group
1	Argentina	Upper middle income	18	Jamaica	Upper middle income	35	Australia	High-income: OECD	51	Italy	High-income: OECD
2	Bangladesh	Low income	19	Lesotho	Lower middle income	36	Austria	High-income: OECD	52	Japan	High-income: OECD
3	Belarus	Upper middle income	20	Malaysia	Upper middle income	37	Belgium	High-income: OECD	53	Korea, Rep.	High-income: OECD
4	Bhutan	Lower middle income	21	Maldives	Upper middle income	38	Canada	High-income: OECD	54	Luxembourg	High-income: OECD
5	Bolivia	Lower middle income	22	Mauritius	Upper middle income	39	Chile	High-income: OECD	55	Netherlands	High-income: OECD
6	Brazil	Upper middle income	23	Moldova	Lower middle income	40	Czech Republic	High-income: OECD	56	New Zealand	High-income: OECD
7	Bulgaria	Upper middle income	24	Mongolia	Lower middle income	41	Denmark	High-income: OECD	57	Norway	High-income: OECD
8	Burundi	Low income	25	Morocco	Lower middle income	42	Estonia	High-income: OECD	58	Poland	High-income: OECD
9	Cameroon	Lower middle income	26	Pakistan	Lower middle income	43	Finland	High-income: OECD	59	Portugal	High-income: OECD
10	Costa Rica	Upper middle income	27	Panama	Upper middle income	44	France	High-income: OECD	60	Slovak Republic	High-income: OECD
11	Dominican Republic	Upper middle income	28	Romania	Upper middle income	45	Germany	High-income: OECD	61	Slovenia	High-income: OECD
12	Egypt, Arab Rep.	Lower middle income	29	South Africa	Upper middle income	46	Greece	High-income: OECD	62	Spain	High-income: OECD
13	Ethiopia	Low income	30	Syrian Arab Republic	Lower middle income	47	Hungary	High-income: OECD	63	Sweden	High-income: OECD
14	Georgia	Lower middle income	31	Thailand	Upper middle income	48	Iceland	High-income: OECD	64	Switzerland	High-income: OECD
15	India	Lower middle income	32	Tunisia	Upper middle income	49	Ireland	High-income: OECD	65	United Kingdom	High-income: OECD
16	Indonesia	Lower middle income	33	Turkey	Upper middle income	50	Israel	High-income: OECD	66	United States	High-income: OECD
17	Iran, Islamic Rep.	Upper middle income	34	Ukraine	Lower middle income						

Note: All Sample 2 countries comprise 34 developing countries (low-income and middle-income) and 32 high-income OECD countries.

3.1 Public expenditure and economic growth: government budget constraint (Study 2)

The disaggregated analysis of public expenditure and growth in Chapter 2 followed the framework proposed by Bose et al. (2007), which is subject to potential biases from the omission of government budget constraint except when non-tax revenue is an implicit financing element. In this section, several implicit financing elements used in Kneller et al. (1999) are applied to our growth regressions.

Conforming to Kneller et al.'s (1999) study, public expenditure in this analysis, is broadly classified as productive, non-productive or other expenditure. Government expenditures are productive if they are included as arguments in the private production function. This is congruent with Devarajan et al. (1996) which define productive expenditure as a component of public spending, increase in the share of which will enhance the steady-state rate of growth. By this definition, Kneller et al. (1999) categorise expenditure types with substantial capital components as productive. On the other hand, an increase in the share of non-productive expenditure does not affect the steady-state growth rate.

Government revenue comprises distortionary taxes, non-distortionary taxes and other revenue. Though some might argue that all kinds of taxation are distortionary in certain aspects, Kneller et al. (1999) claim that the relevant distortion when testing the endogenous growth model is that of the incentive to invest in both physical and human capital. While distortionary taxes affect saving and investment decisions, non-distortionary taxes do not reduce the returns on investment. Using these criteria, income and property taxes are the main forms of taxation that are treated as distortionary. Consumption taxes are classified as non-distortionary from a production standpoint, although there might have an effect on the choice between labour and leisure. In addition, we also include budget balance in the government budget, i.e. excess government revenue after expenditure. Each of these variables is presented as a share of GDP. The theoretical definitions of these fiscal variables are included in Table 3-2.

Table 3-2: Theoretical classification of fiscal aggregates

Theoretical classification	Functional classification
Productive expenditure	General public services expenditure (GPS) Defence expenditure (DEF) Education expenditure (EDU) Health expenditure (HEA) Housing expenditure (HOU) Transportation and communication expenditure (TRC)
Non-productive expenditure	Social security and welfare expenditure (SOC) Recreation expenditure (RCR) Economic services expenditure excluding TRC (ECN)
Other expenditure	Other unclassified expenditure (OT)
Distortionary taxes	Taxation on income and profit (TIN) Social security contributions (SSC) Taxation on payroll (TPR) Taxation on property (TPP)
Non-distortionary taxes	Taxation on domestic goods and services (TGS)
Other revenues	Taxation on international trade (TTR) Non-tax revenues (NTA) Other tax revenues (OTT)

Using this framework, the public-policy endogenous growth models predict that a growth-enhancing effect can be derived from obtaining revenue from non-distortionary taxation rather than distortionary taxation, whereas switching expenditure from productive to unproductive forms deteriorates economic growth (Kneller et al., 1999). An increase in productive expenditure financed by non-distortionary taxation is predicted to have a favourable impact on the rate of growth, whereas the predicted growth effect of using distortionary tax finaincing to increase productive expenditure is unclear. Non-productive expenditure undoubtedly has a growth-damaging impact when funded by distortionary taxation, but is predicted to have no growth effect if funded by non-distortionary taxation.

Like Kneller et al. (1999), Devarajan et al. (1996) predict that shifting the mix of public expenditure towards productive spending will increase the long-term growth rate, providing that the relative shares of productive and non-productive expenditure are below their relative output elasticities. Moreover, they argue that an increase in total government expenditure will only increase the steady-state rate of growth if the productivity of that spending is greater than that of the taxes used to finance it.

Focussing on the growth effects of the broad categories of fiscal variables, the set of non-fiscal control variables are those found in the Barro-type regression. This includes initial GDP per capita (IGDPPAX1P), gross capital formation (K) as a share of GDP and labour force growth (LG). Since this study is primarily concerned with the role played by different implicit financing elements, we have not used the robustness test where other types of non-fiscal control variables are added to the equations. The list of both dependent and control variables in Study 2 is shown in Table 3-3. Annual data between 1991 and 2012 is analysed. This analysis includes data for fewer years than of the analysis featured in the previous chapter, because information about some of the control variables was unavailable for earlier years.

This study, unlike that of Kneller et al. (1999), does not include lending minus repayments due to the unavailability of the data from an accessible source. The omission of this data means that our government budget constraint does not include all constituents. For this reason, it should be noted that the interpretation of each implicit financing element in our analysis partially includes this net repayment item.

Table 3-3: List of variables for Study 2

Variables	**Description of the variables**
GR	Annual GDP per capita growth (%)
IGDPPAX1P	One-year lag of GDP per capita (thousand 2005 USD)
K	Gross capital formation (% of GDP)
LG	Labour force growth (%)
pr_gdp	Productive expenditure (% of GDP)
upr_gdp	Non-productive expenditure (% of GDP)
ot_gdp	Other expenditure (% of GDP)
distax_gdp	Distortionary taxation (% of GDP)
tgs_gdp	Non-distortionary taxation (% of GDP)
otrev_gdp	Other revenue (% of GDP)
SURBP	Budget balance (% of GDP)

The regression technique used in this section is the two-way fixed effects model, which is preferred to the pooled regression, the one-way fixed effects model, the one-way random effects model, and the two-way random effects model, based on the comparison of the adjusted R^2 and the Hausman test.

3.1.1 Government budget constraint: model specification

As pointed out by Kneller et al. (1999), most early studies testing public-policy endogenous growth models fail to take the role of government budget constraint into account appropriately. The estimates which focus only on one side of the budget constraint suffer from systematic bias relating to the assumption of implicit financing elements. When all elements of the government budget are included, one element must be omitted in order to avoid perfect collinearity. That element is regarded as a source or a use of funds when implementing a particular fiscal policy. Miller and Russek (1997) underline the important role played by the method of financing in determining the growth effect of public spending. In other words, the impacts of fiscal policies can be distorted by the way in which these policies are financed.

The implicit financing elements considered in this analysis are non-distortionary taxes and non-productive expenditures. This differs from the method used by Bose et al. (2007), in which non-tax revenue is used as the only implicit financing element. Our assumption is that the omitted variables are neutral, implying that their coefficients should be zero. In fact, non-distortionary taxes and non-productive expenditure might be non-neutral. They are individually omitted from the regression in the first and the second equations. Both are then omitted from the third equation.

$$GR_{it} = \beta_{0t} + \beta_1 IGDPPAX1P_{it} + \beta_2 K_{it} + \beta_3 LG_{it} + \beta_4 SURBP_{it} + \beta_5 otrev\_gdp_{it} + \beta_6 ot\_gdp_{it} + \beta_7 distax\_gdp_{it} + \beta_9 pr\_gdp_{it} + \beta_{10} upr\_gdp_{it} + u_{it} \quad (1)$$

$$GR_{it} = \beta_{0t} + \beta_1 IGDPPAX1P_{it} + \beta_2 K_{it} + \beta_3 LG_{it} + \beta_4 SURBP_{it} + \beta_5 otrev\_gdp_{it} + \beta_6 ot\_gdp_{it} + \beta_7 distax\_gdp_{it} + \beta_8 tgs\_gdp_{it} + \beta_9 pr\_gdp_{it} + u_{it} \quad (2)$$

$$GR_{it} = \beta_{0t} + \beta_1 IGDPPAX1P_{it} + \beta_2 K_{it} + \beta_3 LG_{it} + \beta_4 SURBP_{it} + \beta_5 otrev\_gdp_{it} + \beta_6 ot\_gdp_{it} + \beta_7 distax\_gdp_{it} + \beta_9 pr\_gdp_{it} + u_{it} \quad (3)$$

The coefficient of each fiscal variable is the effect of a unit change in that relevant fiscal variable offset by the effect of a unit change in the omitted fiscal variable.

In Equation (1), non-distortionary taxation is chosen as the implicit financing element. The coefficient of each remaining fiscal variable is the effect of a unit change in that relevant fiscal variable offset by the effect of a unit change in non-distortionary taxation as a share of GDP.

When non-productive expenditure is an implicit financing element in Equation (2), the coefficient of each fiscal variable is the effect of a unit change of that fiscal variable offset by the effect of a unit change in non-productive expenditure as a share of GDP.

Both non-distortionary taxation and non-productive expenditure are omitted from Equation (3). The coefficient of each fiscal variable can be interpreted as an effect of its change offset by the combining effect of a unit change in both non-distortionary taxation and non-productive expenditure as a share of GDP.

The regression results will be discussed for the groups of developing countries and high-income OECD countries within Sample 2 in next subsection.

3.1.2 The results for developing Sample 2 countries

The results for developing Sample 2 countries in Table 3-4 show that initial GDP per capita, gross capital formation, budget surplus and distortionary taxes are significantly related to growth. Labour force growth, other revenue, productive expenditure, non-productive expenditure and non-distortionary taxation have insignificant coefficients. Some of the coefficients of other expenditure are significantly related to growth.

The negative coefficients of initial GDP per capita confirm the conditional convergence hypothesis within a group of developing Sample 2 countries. An increase in gross capital formation by 1% of GDP can enhance GDP per capita growth by 0.16%.

The fiscal variables are not all significantly related to rate of growth. There is no evidence that an increase in productive expenditure has a growth-promoting effect, regardless of the choice of implicit financing element. In particular, there is no evidence to support the theoretical prediction that an increase in productive expenditure financed by non-distortionary taxation has a favourable impact on growth rate for developing Sample 2 countries. The

insignificant growth effect of an increase in productive expenditure might arise from the mixture of spending by functions which may individually have positive or negative impacts.

Table 3-4: Growth regressions of developing Sample 2 countries with government budget constraint

Estimation method	Two-way FE	Two-way FE	Two-way FE
Dependent variable	GR	GR	GR
Implicit financing element	tgs_gdp	upr_gdp	tgs_gdp upr_gdp
	(1)	**(2)**	**(3)**
Regressor	**b/se**	**b/se**	**b/se**
Initial GDP per capita	-3.626***	-3.626***	-3.586***
	(0.58)	(0.58)	(0.58)
Gross capital formation (% of GDP)	0.155***	0.155***	0.162***
	(0.03)	(0.03)	(0.03)
Labour force growth (%)	0.021	0.021	0.026
	(0.10)	(0.10)	(0.10)
Budget balance (% of GDP)	0.500***	0.315***	0.365***
	(0.14)	(0.09)	(0.08)
Other revenue (% of GDP)	-0.158	0.027	-0.026
	(0.14)	(0.09)	(0.08)
Other expenditure (% of GDP)	0.327**	0.142	0.175**
	(0.15)	(0.09)	(0.08)
Distortionary taxes (% of GDP)	-0.655***	-0.470***	-0.489***
	(0.17)	(0.11)	(0.11)
Productive expenditure (% of GDP)	0.105	-0.080	-0.014
	(0.13)	(0.10)	(0.08)
Non-productive expenditure (% of GDP)	0.185		
	(0.15)		
Non-distortionary taxes (% of GDP)		0.185	
		(0.15)	
Adjusted-R^2	0.238	0.238	0.237
N	450	450	450
N_g	34	34	34

Notes: Standard errors in parentheses below parameters

***, **, * Statistical significance at 1%, 5% and 10% respectively

This can be seen in our disaggregated analysis in Chapter 2, where an increase in transportation and communication spending has a growth-promoting effect, while an increase in education spending has a growth-deteriorating effect. However, an increase in other expenditure is conducive to growth unless it is

being financed solely by the reduction of non-productive expenditure. While an improvement in budget balance is growth-enhancing, an increase in distortionary taxation deteriorates growth in developing Sample 2 countries.

3.1.3 The results for high-income OECD Sample 2 countries

As seen in Table 3-5, in high-income OECD Sample 2 countries, initial GDP per capita, gross capital formation and labour force growth are significantly related to growth. As in the results for developing Sample 2 countries, there is clear evidence of conditional convergence in high-income OECD Sample 2 countries. The positive impact of a 1% increase in gross capital formation contributes to around 0.26% of GDP per capita growth, which is higher than that of developing Sample 2 countries. An increase in labour force growth is conducive to per capita growth rate in high-income OECD Sample 2 countries. In contrast, the estimates of developing Sample 2 countries show that increased labour force growth has an insignificant effect on per capita growth rate. The impacts of other fiscal variables on growth depend on different implicit financing elements. Fiscal policy effectiveness is clearly shown to be mainly driven by financing which involves non-productive expenditure.

An improvement in budget balance can be conducive to growth if it is induced by decreasing non-productive expenditure. The positive effect still exists when combining a decrease of non-productive expenditure with an increase in non-distortionary taxes.

An increase in distortionary taxes is obviously growth-deteriorating, especially when it is used for non-productive expenditure.

An increase in other expenditure and productive expenditure is growth-promoting when financed by a decrease in non-productive expenditure, or a combination of a decrease in non-productive expenditure and an increase in non-distortionary taxes. A 1% of GDP increase in productive expenditure can improve GDP per capita growth by 0.16% to 0.26%, depending on different implicit financing elements. This favourable growth impact of shifting spending from unproductive to productive forms supports the theoretical prediction discussed previously.

Table 3-5: Growth regressions of high-income OECD Sample 2 countries with government budget constraint

Estimation method	Two-way FE	Two-way FE	Two-way FE
Dependent variable	GR	GR	GR
Implicit financing element	tgs_gdp	upr_gdp	tgs_gdp upr_gdp
	(1)	**(2)**	**(3)**
Regressor	**b/se**	**b/se**	**b/se**
Initial GDP per capita	-0.233***	-0.233***	-0.218***
	(0.03)	(0.03)	(0.03)
Gross capital formation (% of GDP)	0.257***	0.257***	0.255***
	(0.04)	(0.04)	(0.04)
Labour force growth (%)	0.177**	0.177**	0.164**
	(0.07)	(0.07)	(0.07)
Budget balance (% of GDP)	-0.142	0.237***	0.179***
	(0.11)	(0.05)	(0.05)
Other revenue (% of GDP)	0.108	-0.272***	-0.203**
	(0.13)	(0.09)	(0.08)
Other expenditure (% of GDP)	-0.088	0.291***	0.182**
	(0.12)	(0.09)	(0.08)
Distortionary taxes (% of GDP)	0.091	-0.289***	-0.213***
	(0.11)	(0.06)	(0.06)
Productive expenditure (% of GDP)	-0.120	0.260***	0.161**
	(0.11)	(0.08)	(0.07)
Non-productive expenditure (% of GDP)	-0.380***		
	(0.12)		
Non-distortionary taxes (% of GDP)		-0.380***	
		(0.12)	
Adjusted-R^2	0.510	0.510	0.502
N	587	587	587
N_g	32	32	32

Notes: Standard errors in parentheses below parameters

***, **, * Statistical significance at 1%, 5% and 10% respectively

In conclusion, in Study 2, the evidence of an increase in productive expenditure being conducive to growth exists only in high-income OECD Sample 2 countries. The growth-deteriorating effect of distortionary taxes is obvious in countries with different income levels. Gross capital formation is positively related to growth, whereas initial GDP per capita is negatively related to growth in both groups of Sample 2 countries.

3.1.4 Comparison of our Study 2 results with those of Kneller et al. (1999)

The results for our high-income OECD Sample 2 countries can be compared with the findings of Kneller et al. (1999). We analyse annual data between 1991 and 2012, whereas Kneller et al. (1999) use five-year averages between 1970 and 1995. The relationship between each independent variable and growth is listed in Table 3-6.

Table 3-6: Comparison between the study of Kneller et al (1999) and our Study 2

Variables/ studies	Kneller et al. (1999)	Our study
Initial GDP	Negatively significant	Negatively significant
Investment	Insignificant	Positively significant
Labour force growth	Insignificant	Positively significant
Productive expenditure	Positively significant	Mostly positively significant
Other expenditure	Positively significant	Mostly positively significant
Distortionary taxes	Negatively significant	Mostly negatively significant
Other revenues	Insignificant	Mostly negatively significant
Budget balance	Positively significant	Mostly positively significant

When considering control variables, initial GDP per capita has a significant negative coefficient in both studies. Conditional convergence can be identified in both studies in different periods. This evidence is also consistent with the findings of other studies which take government budget constraint into account, i.e. Miller and Russek (1997), and Morozumi and Veiga (2016). While both investment ratio and labour force growth are positively related to economic growth in our study, neither is significant in Kneller et al. (1999). Our findings for investment ratio is supported by both Miller and Russek (1997), and Morozumi and Veiga (2016). While the positive growth effects of investment conform appropriately to the theoretical prediction, the favourable growth impacts of labour force growth may require an increase in productivity of labour.

When comparing the estimated coefficients of fiscal variables with Kneller et al. (1999), we find that productive expenditure, other expenditure and budget surplus are conducive to growth in both studies, while an increase in

distortionary taxes reduces rates of growth. Other revenues have an insignificant relationship with growth in Kneller et al. (1999). However, this variable has a negative significant coefficient in our study.

Though the estimated results from our study are similar to those of Kneller et al. (1999), we have found that fiscal changes mainly affect GDP per capita growth through non-productive expenditure financing for high-income OECD Sample 2 countries. The favourable growth impact might be lessened when the implicit financing elements combine non-productive expenditure and non-distortionary taxes. Both elements seem to generate similar growth effects in Kneller et al. (1999).

The contradicting results of growth effects from fiscal changes regarding different implicit financing elements are, however, supported by Miller and Russek (1997), and Morozumi and Veiga (2016). In the sample of developed countries in Miller and Russek (1997), deficit-financed increases in government expenditure do not affect economic growth and tax-financed increases lead to lower growth. When combining high-income and developing countries, Morozumi and Veiga (2016) found that a rise in total spending financed through revenue has a positive effect on growth, while an increase in total spending financed by higher deficits has an insignificant growth impact. These findings confirm that sources of funds play important roles in determining the growth effect of increased public spending, but also show that growth effects can vary between the groups of countries used for analysis, especially those with different income levels. The different effects seen when studying different periods might suggest the existence of fiscal policy decision dynamics.

In the next section, we consider the impacts of fiscal changes on the level of long-run GDP.

3.2 Public spending and long-run GDP level (Study 3)

3.2.1 Introduction

The fiscal-growth studies in Chapter 2 and Section 3.1 of Chapter 3 focus on the public-policy endogenous growth model. In those studies, permanent growth effects of fiscal changes are analysed without transitional dynamics. The

analysis of fiscal policy impacts in this section allows for Solow-type transitional dynamics, but the effects of fiscal policy may be persistent according to the framework proposed by Gemmell et al. (2016).

Gemmell et al.'s (2016) study was motivated by the recent fiscal stimulus enacted after 2009 in order to counteract the global financial crisis. Governments' spending choices in these short-term packages are partially influenced by their ambitions to comply with long-term growth objectives. With these policy objectives, there are two different questions to be addressed: how forceful is the evidence that long-run income levels or growth rates react to changes in public spending, and if they do, which expenditure types produce most considerable impacts? Later in this section, we attempt to respond to these questions by looking at both developing countries and high-income OECD countries. The study in this section will be referred to as Study 3 and use Sample 3 countries.

3.2.2 Literature review

In terms of the period of study, recent studies on fiscal policy and long-run size of economy (either level of GDP or rate of growth) include recent data, especially the Acosta-Ormaechea and Morozumi's (2013) study which uses data from 1970 to 2010. Other studies (Afonso & Jalles, 2014; Arnold et al., 2011; Gemmell et al., 2011; Gemmell et al., 2016; Xing, 2012) also cover periods from the 1970s until 2010. Ojede and Yamarik (2012) focus on an earlier period; 1967 to 2008.

In terms of the sets of fiscal variables used, these studies either put emphasis on tax policy (Arnold et al., 2011; Ojede & Yamarik, 2012; Xing, 2012), public spending (Gemmell et al., 2016), or both types of variables at once (Afonso & Jalles, 2014; Gemmell et al., 2011). In addition, Afonso and Jalles (2014) look at both functional and economic classes of fiscal variables according to the Government Finance Statistics (GFS) definitions provided by the International Monetary Fund (IMF).

As well as being categorised by their focus (on revenue and/or expenditure), the effects of fiscal changes can be classified by their impact on the size of economy (short-run or long-run impact). Some of these studies focus

only on permanent growth effects (Acosta-Ormaechea & Morozumi, 2013; Afonso & Jalles, 2014), while others distinguish between the long-run and short-run impacts of changes in fiscal variables (Arnold et al., 2011; Gemmell et al., 2011; Gemmell et al., 2016; Ojede & Yamarik, 2012; Xing, 2012). Our study pays specific attention to the latter set of studies.

While many studies that differentiate between the long-run and short-run effects of fiscal change capture the size of an economy by using the growth rate of GDP or the growth rate of GDP per capita, Arnold et al. (2011), Xing (2012) and Gemmell et al. (2016) use the level of per capita GDP. Gemmell et al. (2016) claim that using this specification is advantageous because it allows the degree of persistence in GDP growth responses to be identified by the data, rather than by using a functional form incorporating permanent effects. For this reason, our study will focus on the impact on level of GDP per capita.

The three studies referred to above use cross-country data, whereas Ojede and Yamarik (2012) evaluate the growth effects of tax policy at state level. Instead of investigating the growth effects of fiscal policy, Lamartina and Zaghini (2011) test the validity of Wagner's law in high-income OECD countries.

Although there are differences in the model specifications for investigating change in fiscal composition and their effects on either the level of GDP or economic growth, the findings are, to a certain degree, harmoniously aligned. We go on to discuss previous findings, econometric methods, included variables in the model, the role played by budget constraint, and other econometric issues in these studies.

3.2.2.1 Previous findings

This strand of literature, like the permanent growth effects of fiscal change studies in Chapter 2 and Section 3.1 of Chapter 3, mainly considers high-income countries and, more specifically, high-income OECD countries (Arnold et al., 2011; Gemmell et al., 2011, Gemmell et al., 2016; Xing, 2012). Other studies, e.g. Acosta-Ormaechea and Morozumi (2013) and Afonso and Jalles (2014), consider a wider set of countries.

Some studies find the reallocation of fiscal composition to be robustly related to long-run growth or GDP level, while others do not. In order to

understand this incongruity clearly, we need to take several aspects of the preceding results into consideration. Firstly, there are two different types of fiscal variables being considered, namely public expenditure and public revenue. Secondly, we need to consider the way in which an increase in public expenditure is financed. We previously refer to this as an implicit financing element. For example, Gemmell et al. (2016) find that an increase in total spending enhances GDP per capita level in the long run when financed by non-distortionary taxes. Thirdly, fiscal variable classifications can be interpreted differently when we analyse the impacts of changes in these variables on GDP or growth of GDP. This depends on the aspect of fiscal change we need to evaluate in order to assess its impact. The following paragraphs summarise the key findings of the papers mentioned earlier.

Arnold et al. (2011) find that shifting taxes on income towards consumption and immovable property enhances long-run GDP per capita. In particular, increasing revenue by raising current taxes on immovable property and consumption is least harmful to growth. Arnold et al.'s (2011) findings are supported by Xing (2012), suggesting that shifting tax revenue away from corporate income, personal income, and consumption taxes, and towards property taxes is associated with a higher level of income per capita in the long run.

When investigating state-level data, Ojede and Yamarik (2012) obtained different results from Arnold et al. (2011) and Xing (2012). They found that increases in sales and property taxes reduce long-run real income growth.

Gemmell et al. (2011) observe that the growth effects of fiscal policy in the short run appear to persist. Although some fiscal variables only have transitory effects, others might have persistent growth effects. However, the positive growth effects associated with productive spending are often counteracted by the negative effects of tax changes.

Gemmell et al. (2016) raise awareness of the significance of financing methods for increasing any type of public expenditure when determining long-run GDP level. By using pooled mean group estimators (PMG) with contemporaneous correlation, they find robust long-run positive effects on GDP per capita levels for reallocating total spending towards transportation and communication, and education spending.

In contrast, Afonso and Jalles (2014) find that revenue has no significant impact on growth. Moreover, government expenditures appear to have highly significant negative signs.

Acosta-Ormaechea and Morozumi (2013) find that an increase in education spending offset by a fall in social spending seems to be robustly related to higher growth rates. These results also hold true at the general government level. Their results also show that education spending promotes growth as well as public capital does in the long run. Additionally, they note that finding proxies for the quality of public spending would be challenging.

3.2.2.2 Improvement of econometric methods

Recent developments in data collection has improved the availability of data, so it has become possible to investigate the compositional change of public spending and its impact on long-run GDP per capita level or growth.

The updated data can be used under the assumptions of short-run heterogeneity and long-run homogeneity. This econometric method proposed by Pesaran et al. (1999) is pooled mean group estimators (PMG). It is a compromise between the fixed effects model and the mean group estimator (MG). While intercept, short-run coefficients and error variances are allowed to differ across groups, the long-run coefficients are equal. This method has been analysed by Arnold et al. (2011), Gemmell et al. (2011), Ojede and Yamarik (2012), Xing (2012), and Gemmell et al. (2016).

3.2.2.3 Variables included in recent studies

- *Dependent variable*

The choice of dependent variable is distinctly separable between growth of GDP and level of GDP. While most studies use the growth rate of either GDP or GDP per capita, Arnold et al. (2011) use a change in log of GDP per capita and a change in log of TFP of a given firm. Similarly, Xing (2012) also uses a change in log of real GDP per capita as a dependent variable. While Gemmell et al. (2011) use a change in the growth rate of GDP in one of their studies, the

level of GDP per capita is employed by Gemmell et al. (2016). The dependent variable in Ojede and Yamarik (2012) is the change in growth rate of real income.

It is important to note that all of these studies (Arnold et al., 2011; Gemmell et al., 2011, Gemmell et al., 2016; Ojede & Yamarik, 2012; Xing, 2012) estimate the results with an error correction model. When interpreting the results, we need to refer back to the equations in terms of the autoregressive distributed lag model: i.e. the long-run level of GDP per capita impact from fiscal change is analysed in Xing (2012), rather than the growth effect (change in log of real GDP per capita).

Afonso and Jalles (2014) use the real growth rate of GDP per capita, and Acosta-Ormaechea and Morozumi (2013) select the growth of output per capita.

- *Fiscal variables*

Different classes of expenditure and revenue can be considered. Two broad categories of each type of fiscal variables are included, following the example of Kneller et al. (1999) and based on the framework proposed by Barro (1990); namely productive expenditure, unproductive expenditure, distortionary taxes and non-distortionary taxes. These categories have already been defined in Section 3.1. We will now describe some of the fiscal variables included in recent studies.

Arnold et al. (2011) focus on tax structures which can be classified mainly into income taxes, consumption taxes and property taxes. Ojede and Yamarik (2012) and Xing (2012) also emphasise on the composition of tax revenues.

Gemmell et al. (2011) use broad categories of revenue and expenditure: productive expenditure, non-productive expenditure, distortionary taxes and non-distortionary taxes. Gemmell et al. (2016) utilise broad categories of revenue similar to those used by Gemmell et al. (2011) and functional classifications of public expenditure, namely transportation and communication, education, health and housing etc.

Afonso and Jalles (2014) focus on both aggregate levels and GFS (Government Finance Statistics) classifications of fiscal variables. This includes

functional and economic classifications of both government expenditure and revenue. Acosta-Ormaechea and Morozumi (2013) also look at both economic and functional classifications of public expenditure. Economic classifications include the compensation of employees, other expenses and the net acquisition of non-financial assets. Functional classifications include defence, transportation and communication, health, education, and social protection expenditures.

- *Non-fiscal control variables*

A number of factors can be used as non-fiscal control variables. The criteria used to decide which should be chosen are highly dependent on the type of question or particular model being investigated. Since using pooled mean group estimators limits the number of control variables due to a decrease in the degree of freedom, this strand of literature often only includes a few non-fiscal control variables in analyses.

Arnold et al. (2011) and Xing (2012) include investment rate, human capital and population growth. Gemmell et al. (2011) and Gemmell et al. (2016) use investment rate and employment growth. Like Gemmell et al. (2011, 2016), Ojede and Yamarik (2012) include growth in private employment and private investment share in their set of non-fiscal control variables.

While Afonso and Jalles (2014) use population growth, investment, education and trade openness, Acosta-Ormaechea and Morozumi (2013) include initial GDP per capita and initial human capital in their set of non-fiscal control variables.

3.2.2.4 The role of government budget constraint

Government budget constraint needs to be considered in order to avoid the production of invalid results due to biases occurring as a result of not including both revenue and spending variables in the same equation. This issue has been explained in Chapter 1 and Chapter 2. Recent studies take government budget constraint into account while avoiding perfect multicollinearity in accordance

with the specification in Kneller et al. (1999). The important role played by the implicit financing element is highly relevant in this analysis.

3.2.2.5 Other econometric issues

There are also other econometric issues which should be addressed, such as endogeneity and a robustness check.

Firstly, Afonso and Jalles (2014) investigate the robustness of their results by adding variables (labour force participation and unemployment rates) into the baseline regression. Similarly, Acosta-Ormaechea and Morozumi (2013) add inflation, openness, population growth and terms of trade growth into their original set of control variables. Different specifications, including lagged fiscal variables and the different developmental levels of countries in the sample, might also be considered.

Secondly, using pooled mean group estimators to analyse the error-correction model might require some tests as prerequisites. Gemmell et al. (2016) tested the order of integration and cointegration, autoregressive distributed (ARDL) lag structure, and weak exogeneity. They found that their variables are best treated as non-stationary. Imposing two-lags of ARDL tends to strengthen the case for significant causal effects from a number of public spending categories on the level of long-run GDP per capita. Their estimated results offer relatively strong support for the theory that expenditure share variables can be considered to be weakly exogenous, allowing interpretation of the estimated long-run expenditure parameters as capturing causal effects on GDP. The issues tested in Gemmell et al. (2016) will be further investigated in Subsection 3.2.4 of our study. Public expenditure composition is analysed in the next subsection.

3.2.3 Public expenditure composition of Sample 3 countries

In this subsection, we analyse the data on public expenditure composition for 38 selected countries in Sample 3 according to the availability of control variables, which is mainly affected by labour growth. The set of Sample 3 countries in Table 3-7 is divided into two main groups: developing countries and high-

income OECD countries. The group of developing countries includes 17 countries, referred to as developing Sample 3 countries. The group of high-income OECD countries consists of 21 countries, referred to as high-income OECD Sample 3 countries.

Table 3-7: List of Sample 3 countries in Study 3 by group

Developing countries		**High-income OECD countries**	
Bolivia	Morocco	**Austria***	Korea, Rep.
Brazil	South Africa	**Canada***	**Luxembourg***
Cameroon	Thailand	Chile	**Netherlands***
Costa Rica	Tunisia	**Denmark***	**New Zealand***
Dominican Republic	Turkey	**Finland***	**Norway***
Egypt, Arab Rep.	Nepal	**France***	Portugal
India		Hungary	**Spain***
Indonesia		**Iceland***	**Sweden***
Iran, Islamic Rep.		Ireland	**UK***
Malaysia		Israel	**United States***
Mauritius		Italy	

Note: * Our 14 OECD countries included in Gemmell et al.'s (2016) group of 17 OECD countries

As shown in Figure 3-1, total public spending in the group of Sample 3 countries has slightly increased in the past four decades. This can be seen from the increase in unweighted 10-year average total spending to GDP from 23.42% in 1972-1981 to 25.44% in 2002-2011 for developing Sample 3 countries. For high-income OECD Sample 3 countries, the level of total public spending to GDP increased from 32.55% in 1972-1981 to 35.19% in 2002-2011. Public spending in high-income OECD Sample 3 countries increased significantly during the 1970s and 1980s, but subsided in later periods. On the other hand, the proportion of government spending to GDP in developing Sample 3 countries increased consistently during 1992-2001 and 2002-2011.

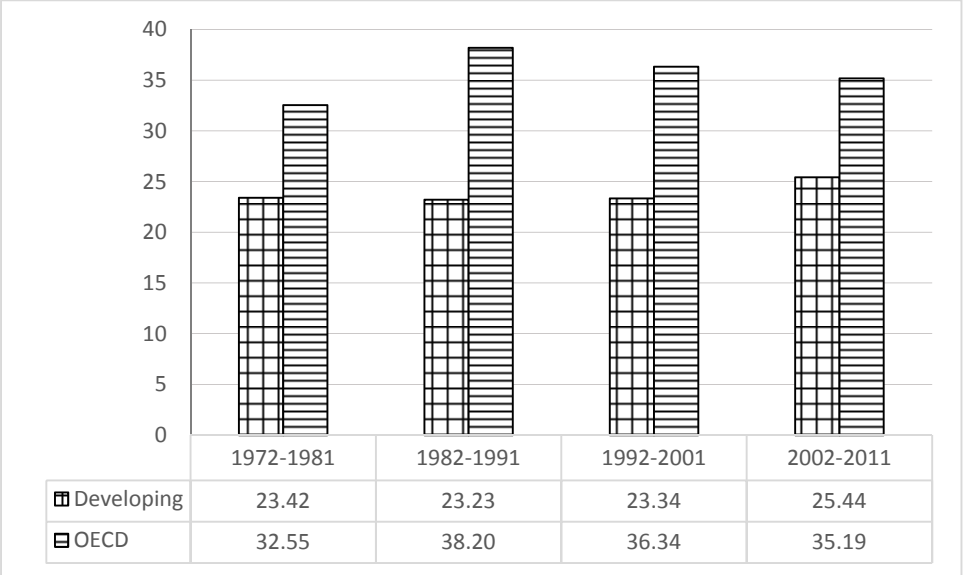


Figure 3-1: Unweighted 10-year averages of total public spending as percentages of GDP for groups of Sample 3 countries (1972-2011)

3.2.3.1 The composition of public spending

Table 3-8 presents the average amount of particular types of public spending by Sample 3's groups of countries as percentages of GDP. In percentage terms, government spending in high-income OECD Sample 3 countries is obviously higher than in developing Sample 3 countries. The same also applies to many other types of spending, although not to spending on general public services. The level of spending on education as a share of GDP is relatively similar across different groups of Sample 3 countries, with an average of around 3.38% of GDP.

Table 3-8: Unweighted averages of public spending by type as percentages of GDP for groups of Sample 3 countries (1972-2012)

	Developing countries	**High-income OECD countries**
Total spending	23.96	35.74
General public services	3.80	2.73
Defence	2.07	2.41
Transportation and communication	1.42	1.64
Education	3.38	3.39
Healthcare	1.45	3.62
Social welfare	3.13	12.59

The composition of public spending in different groups of countries varies depending on the policies and problems that particular governments encounter. The unweighted averages of public spending by type as percentages of total spending from 1972 to 2012 for developing Sample 3 countries and high-income OECD Sample 3 countries are shown in Table 3-9. In developing Sample 3 countries, general public services (16.2%), education (14.1%) and social welfare (11.9%) spending are crucial elements of government budgets. In contrast, high-income OECD Sample 3 countries spend a large proportion of public expenditure on social welfare (34.7%), healthcare (10.1%) and education (9.7%). Social welfare spending accounts for more than a third of total public spending in high-income OECD Sample 3 countries.

Table 3-9: Unweighted averages of public spending by type as percentages of total spending for groups of Sample 3 countries (1972-2012)

	Developing countries	**High-income OECD countries**
General public services	16.20	7.65
Defence	8.69	7.30
Transportation and communication	6.51	4.71
Education	14.10	9.67
Healthcare	6.23	10.05
Social welfare	11.93	34.72

The public spending composition of developing Sample 3 countries is presented in Figure 3-2 using unweighted 10-year averages for the period from 1972 to 2011. It is clear that social welfare spending as a proportion of total public spending has increased significantly over time. In contrast, spending on defence, and transportation and communication has decreased significantly relative to other types of public spending.

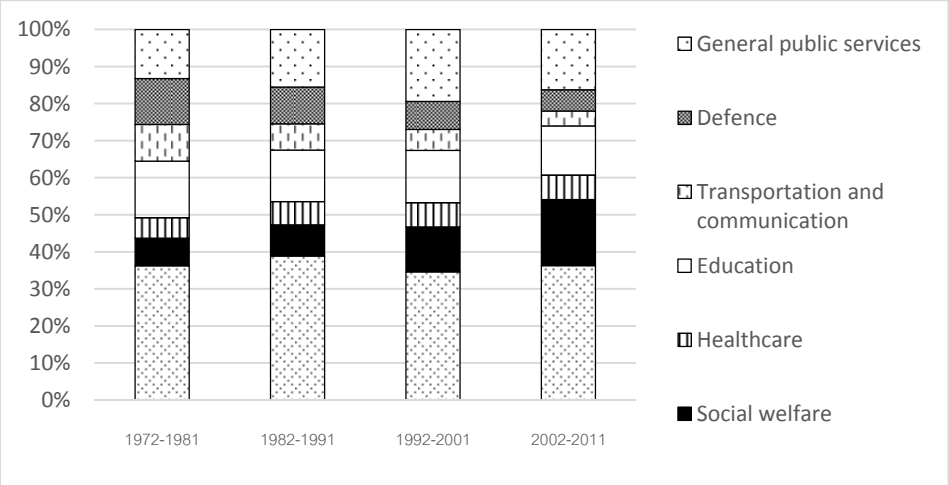


Figure 3-2: Unweighted 10-year averages of spending by type as percentages of total spending for developing Sample 3 countries (1972-2011)

The proportions of most spending types, including general public services, education and social welfare spending, in relation to total spending in high-income OECD Sample 3 countries have not changed dramatically in the past forty years as can be seen in Figure 3-3. Healthcare spending has increased more noticeably over time than other types of expenditure, whereas spending on defence has been decreasing.

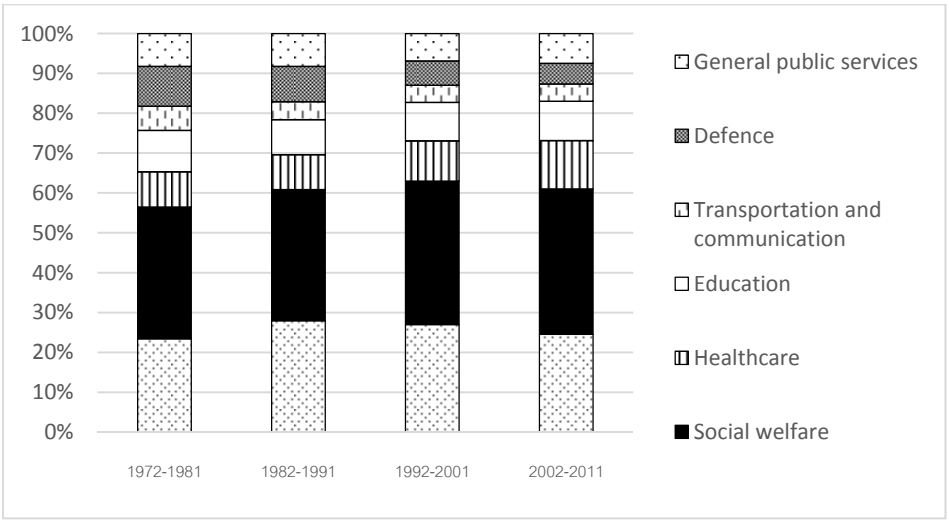


Figure 3-3: Unweighted 10-year averages of spending by type as percentages of total spending for high-income OECD Sample 3 countries (1972-2011)

The following subsection explains the estimation method used to analyse long-run relationship between fiscal variables and GDP per capita.

3.2.4 Public spending and long-run GDP per capita investigating heterogeneous panel data: estimation method

In this subsection, we discuss the econometric methods used to study the relationship between public spending and long-run levels of GDP per capita in Sample 3's groups of countries. Later (in Subsection 3.2.5), we present the estimates separately, according to the Sample 3 country groupings, i.e. developing countries and high-income OECD countries. This subsection (3.2.4) includes the discussion of pooled mean group estimator (PMG), and tests for cointegration and ARDL lag structure.

3.2.4.1 Pooled mean group (PMG) estimator

The endogenous growth model in Devarajan et al. (1996) captures the permanent growth effects from fiscal changes without transitional dynamics (Gemmell et al., 2016). Allowing for Solow-type transitional dynamics while the effects of fiscal change may be persistent requires a more flexible functional form than that of Devarajan et al. (1996). Using an autoregressive distributed lag (ARDL) model parameterised in error correction form in Gemmell et al. (2016) allows both the short-run dynamic and the long-run equilibrium relationships between GDP and fiscal variables to be identified separately. The ARDL(p,q) specification is:

$$y_{i,t} = \sum_{j=1}^{p} \alpha_{i,j} y_{i,t-j} + \sum_{j=0}^{q} \beta_{i,j} X_{i,t-j} + \mu_i + \varepsilon_{i,t} \quad (4)$$

where $X_{i,t-j}$ includes all explanatory variables. Equation (4) can be expressed in error correction form:

$$g_{i,t} = \Delta y_{i,t} = \emptyset_i \left(y_{i,t-1} - \beta_i X_{i,t}\right) + \sum_{j=1}^{p-1} \alpha^*_{i,j} \Delta y_{i,t-j} + \sum_{j=0}^{q-1} \beta^*_{i,j} \Delta X_{i,t-j} + \mu_i + \varepsilon_{i,t} \quad (5)$$

where $\emptyset_i$ captures the error correcting speed of adjustment and β_i captures the long-run equilibrium relationship between y and X with short-run effects measured by $\beta^*_{i,j}$. The estimates of long-run coefficient β_i are not affected by the

choice between $X_{i,t}$ and $X_{i,t-1}$ in determining the long-run relationship. While Arnold et al. (2011), Ojede and Yamarik (2012), and Xing (2012) use $X_{i,t}$, Gemmell et al. (2011, 2016) prefer $X_{i,t-1}$. We use $X_{i,t}$ in our study, since it provides better computational convenience in our statistical package than using $X_{i,t-1}$.

Blackburne and Frank (2007) suggest several approaches which can be taken in order to estimate Equation (5). Firstly, a fixed effect (FE) estimation approach could be used when data from each group is pooled and only the intercepts are allowed to differ across groups. Pesaran and Smith (1995) show that these regressions are likely to be biased if the assumption of homogeneity of the short-run parameter estimates across countries is rejected. Secondly, the model might be fitted separately for each group and the arithmetic average of coefficients could be calculated by using mean group estimators (MG). The MG estimators allow both short and long-run parameter heterogeneity. Thirdly, Pesaran et al. (1999) proposed a PMG estimation that combines both methods of pooling (FE) and averaging (MG). The intercept, short-run coefficients and error variances are allowed to differ across groups, but the long-run coefficients are constrained to be equal across groups. Furthermore, Pesaran et al. (1999) have also demonstrated that allowing for short-run parameter heterogeneity results in more reliable estimates of the long-run responses.

We present the results of PMG estimates, as the Hausman test prefers PMG to MG (see Appendix 3). The implication of the results from the Hausman test is that the assumption of homogenous long-run parameter estimates across countries is valid. The PMG method selected is then comparable to Gemmell et al.'s (2016) study.

This part of our study investigates the long-run relationship between public spending and the GDP per capita level of the 38 countries in Sample 3 (see Table 3-7) which are classified as developing countries (17 countries) and high-income OECD countries (21 countries). These groups of Sample 3 countries were selected based on the availability of control and fiscal variables. The groups of developing countries and high-income OECD countries in Sample 3 have been analysed separately, in a similar way to Gemmell et al. (2016), by looking at the effects of total public expenditure and public expenditure composition. Our study period is 1972-2012.

Our dependent variable $g_{i,t}$ is the change in log of GDP per capita. Although the growth rate of per capita GDP is the dependent variable, as shown in Equation (5), the regression measures the impacts of fiscal and other variables on long-run per capita GDP level. Equation (5) is just a re-parameterisation of Equation (4). As discussed earlier, Gemmell et al. (2016) argue that using level specification allows the identification of the degree of persistence in GDP growth responses.

The non-fiscal control variables included in this study are labour force growth (LG) and investment ratio to GDP (K). Labour force growth before 1990 is assumed to be constant (from the average of available data) in a number of Sample 3 countries where accurate data is not readily available. When taking government budget constraint into account, our fiscal control variables include the ratio of total expenditure to GDP, distortionary taxes to GDP, non-distortionary taxes to GDP and budget surplus to GDP. The theoretical classification of fiscal variables are discussed in Section 3.1. In the cases where we consider public spending composition, the expenditure share of a particular type of public spending in relation to total public spending is added individually. The list of variables included in Study 3 is shown in Table 3-10.

Table 3-10: List of variables for Study 3

Variables	**Description of the variables**
y	Log of GDP per capita (2005 USD)
K	Gross capital formation (% of GDP)
LG	Labour force growth (%)
tot_gdp	Total public spending (% of GDP)
distax_gdp	Distortionary taxation (% of GDP)
tgs_gdp	Non-distortionary taxation (% of GDP)
SURBP	Budget balance (% of GDP)
TOT	Total public spending in local currency unit
gps_tot	Spending on general public services (% of TOT)
def_tot	Spending on defence (% of TOT)
trc_tot	Spending on transportation and communication (% of TOT)
edu_tot	Spending on education (% of TOT)
hea_tot	Spending on health (% of TOT)
soc_tot	Spending on social welfare (% of TOT)

The first part of the analysis of each group of Sample 3 countries looks at the total public expenditure effect with four different implicit financing elements: budget deficit; distortionary taxes; non-distortionary taxes; and a mix of both distortionary and non-distortionary taxes. In the second part of the analysis, we

use budget deficit as an implicit financing element, focussing on the impact of shifting expenditure towards a particular type of public spending composition on the long-run GDP per capita level. There are two Sample 3 groups of countries considered: developing countries and high-income OECD countries. The model specification will be explained further in Subsection 3.2.5.

Gemmell et al. (2016) raise an endogeneity concern with regard to the potential for simultaneity between GDP per capita and the independent variables, especially the fiscal and investment variables. According to certain conditions relating to the cointegrating relationship, estimates of the long-run parameter vector derived from regression of models from Equation (5) are consistent. In addition, serial correlations can be sufficiently dealt with by using appropriate orders of the ARDL model (Pesaran & Shin, 1998). This implies that the endogeneity problem can be overcome by using an ARDL with sufficiently long lags, provided that the regressors are not cointegrated among themselves. Consistent with Gemmell et al. (2016), the variables are firstly checked to ascertain whether they are I(0) or I(1) and whether they are cointegrated. The appropriate ARDL lag structure is then considered.

3.2.4.2 Tests for cointegration and ARDL lag structure

Before discussing the results, we test the order of integration and cointegration, and the ARDL lag structure. The groups of developing countries and high-income OECD countries within Sample 3 are separately tested. Alhough tests have been performed with regard to both the effects of total expenditure and functional spending, our discussion focusses on the former.

- *Testing the order of integration and cointegration*

We firstly test whether our variables are I(0) or I(1). A non-stationary series is integrated of order d, denote I(d), if it becomes stationary after being differenced d times (Greene, 2012). Like Choi (2001), we use the Fisher-type unit root test, since it can be applied to unbalanced panels. The p-values from the unit root test applied to each group in the panel data are combined to derive an overall test of whether the panel series contains a unit root. The null hypothesis is that

every panel contains a unit root, while the alternative is that at least one panel is stationary. While the evidence of non-stationarity is found in all variables of developing Sample 3 countries, the null hypothesis of investment ratio, labour force growth and budget surplus is rejected for high-income OECD Sample 3 countries. However, the test rejects the null of non-stationarity for each of the variables after taking first differences.

Kwiatkowski et al. (1992) can distinguish series that appear to be stationary, series that appear to have a unit root, and series for which data is not sufficiently informative, by testing both the unit root hypothesis and the stationary hypothesis. Though Kwiatkowski et al.'s (1992) methodology is beyond our scope, it suggests that our unit root test might have low statistical power. This implies that we might falsely reject the null hypothesis of unit root. Hence, our variables are most suited to being treated as non-stationary.

For the cointegration test, we implement Westerlund's (2005) method using variance ratio test statistics. The advantage that this method has over the other tests is that it does not require a correct specification of the data generating process. Other tests require some forms of modelling and estimation to correct for the heteroscedasticity and serial correlation properties of the data. Therefore, the outcomes of other cointegration tests can be very sensitive to these choices. The null hypothesis of Westerlund's (2005) test is no cointegration, while the alternative hypothesis is that the variables are cointegrated in all panels. Another variant of Westerlund's test has the alternative hypothesis that the variables are cointegrated in some of the panels. According to variance ratio test statistics, we reject the null hypothesis of no cointegration for all of our PMG specifications.

With unit root and cointegration tests, our model appears to fulfil the conditions which allow the ARDL model to overcome endogeneity concerns.

- *Testing the ARDL lag structure*

As discussed earlier, the appropriate modification of the orders of the ARDL model is sufficient to deal with the residual serial correlation and the problem of endogenous regressors (Pesaran & Shin, 1998).

Gemmell et al. (2016) discuss the argument that augmentation may be viewed as applying to an initial ARDL(p,q) model where lags are chosen a priori. For example, an initially selected ARDL(1,1) might suffer from endogeneity. This can be corrected by running the ARDL(p,m) model where m≥1. The numbers of lags p and m can be chosen by using the Schwarz Criterion.

However, there is data limitation in our samples, in that second lag cannot be applied to all independent variables. This is partly due to unbalanced panel data. For this reason, our analysis focusses on the ARDL(1,1) model. Our tests on appropriate lag structure using the time series of each country suggest that only a few sample countries require second lag of independent variables. This indirectly implies that the endogeneity problem might not be an issue using the ARDL(1,1) model in our study. In fact, ARDL(1,1) model is also used by Arnold et al. (2011) and Xing (2012).

3.2.5 Public spending and long-run GDP per capita investigating heterogeneous panel data: estimated results

Using the ARDL(1,1) model, the error correction form can be specified in order to analyse the long-run GDP impacts of both changes in total government spending and changes in the shares of different spending types for developing Sample 3 countries and high-income OECD Sample 3 countries.

Firstly, the equations in error correction form, for impact of changes in total spending, can be specified according to different implicit financing elements. The equation in which budget balance is an implicit financing element is represented by Equation (6). While Equation (7) has distortionary taxation as an implicit financing element, non-distortionary taxation is a source of funds in Equation (8). Equation (9) omits both the distortionary and non-distortionary taxation variables.

$$\Delta y_{i,t} = \emptyset_i\left(y_{i,t-1} - \beta_1 K_t - \beta_2 LG_t - \beta_3 tot\_gdp_t - \beta_4 distax\_gdp_t - \beta_5 tgs\_gdp_t\right) + \beta_{1i}^{*}\Delta K_{i,t} + \beta_{2i}^{*}\Delta LG_{i,t} + \beta_{3i}^{*}\Delta tot\_gdp_{i,t} + \beta_{4i}^{*}\Delta distax\_gdp_{i,t} + \beta_{5i}^{*}\Delta tgs\_gdp_{i,t} + \mu_i + \varepsilon_{i,t} \quad (6)$$

$$\Delta y_{i,t} = \emptyset_i\left(y_{i,t-1} - \beta_1 K_t - \beta_2 LG_t - \beta_3 tot\_gdp_t - \beta_4 SURBP_t - \beta_5 tgs\_gdp_t\right) + \beta_{1i}^{*}\Delta K_{i,t} + \beta_{2i}^{*}\Delta LG_{i,t} + \beta_{3i}^{*}\Delta tot\_gdp_{i,t} + \beta_{4i}^{*}\Delta SURBP_{i,t} + \beta_{5i}^{*}\Delta tgs\_gdp_{i,t} + \mu_i + \varepsilon_{i,t} \quad (7)$$

$$\Delta y_{i,t} = \emptyset_i\left(y_{i,t-1} - \beta_1 K_t - \beta_2 LG_t - \beta_3 tot\_gdp_t - \beta_4 SURBP_t - \beta_5 distax\_gdp_t\right) + \beta_{1i}^{*}\Delta K_{i,t} + \beta_{2i}^{*}\Delta LG_{i,t} + \beta_{3i}^{*}\Delta tot\_gdp_{i,t} + \beta_{4i}^{*}\Delta SURBP_{i,t} + \beta_{5i}^{*}\Delta distax\_gdp_{i,t} + \mu_i + \varepsilon_{i,t} \quad (8)$$

$$\Delta y_{i,t} = \emptyset_i\left(y_{i,t-1} - \beta_1 K_t - \beta_2 LG_t - \beta_3 tot\_gdp_t - \beta_4 SURBP_t\right) + \beta_{1i}^{*}\Delta K_{i,t} + \beta_{2i}^{*}\Delta LG_{i,t} + \beta_{3i}^{*}\Delta tot\_gdp_{i,t} + \beta_{4i}^{*}\Delta SURBP_{i,t} + \mu_i + \varepsilon_{i,t} \quad (9)$$

Secondly, the impacts of changes in the shares of different spending types are investigated. As in Gemmell et al. (2016), budget balance is the implicit financing element. It has been claimed that omitting budget balance facilitates interpretation, because deficit-funded tax or expenditure changes have intuitive economic translations. The shares of each public spending category are then added to each equation. Equation (10) illustrates the equation in which the share of general public spending is considered. We also estimate the impacts of changes in the shares of defence, transportation and communication, education, health, and social welfare spending. These are also the main types of spending that we considered in Chapter 2.

$$\Delta y_{i,t} = \emptyset_i\left(y_{i,t-1} - \beta_1 K_t - \beta_2 LG_t - \beta_3 tot\_gdp_t - \beta_4 distax\_gdp_t - \beta_5 tgs\_gdp_t - \beta_6 gps\_tot_t\right) + \beta_{1i}^{*}\Delta K_{i,t} + \beta_{2i}^{*}\Delta LG_{i,t} + \beta_{3i}^{*}\Delta tot\_gdp_{i,t} + \beta_{4i}^{*}\Delta distax\_gdp_{i,t} + \beta_{5i}^{*}\Delta tgs\_gdp_{i,t} + \beta_{6i}^{*}\Delta gps\_tot_{i,t} + \mu_i + \varepsilon_{i,t} \quad (10)$$

We will firstly discuss the long-run GDP impacts of both changes in total government spending and changes in the shares of different spending types for developing Sample 3 countries, followed by a discussion of estimates for high-income OECD Sample 3 countries. Our results of high-income OECD Sample 3 countries will then be compared with previous results from Gemmell et al. (2016) in Subsection 3.2.7.

3.2.5.1 Developing Sample 3 countries (1972-2012)

For the 17 developing Sample 3 countries, the results from the test for total public expenditure effects in Table 3-11 suggest that there is no evidence that an increase in total spending is positively related to long-run GDP per capita.

Table 3-11: PMG for developing Sample 3 countries testing for total public expenditure effects

Estimation method	Pooled mean group estimates			
Dependent variable	Annual GDP per capita growth rate (**Δ**y)			
Implicit financing element	SURBP	DISTAX	TGS	DISTAX, TGS
	(1)	**(2)**	**(3)**	**(4)**
Regressor	**b/se**	**b/se**	**b/se**	**b/se**
Long-run effects				
Investment ratio	0.1446*	0.0407***	0.1111***	0.0057
	(0.08)	(0.01)	(0.03)	(0.03)
Labour growth	-0.5451	-0.0886*	0.2051***	-0.3935*
	(0.34)	(0.05)	(0.07)	(0.22)
Total expenditure	-0.2278**	0.0124	-0.0725**	-0.0799
	(0.11)	(0.01)	(0.03)	(0.05)
Budget balance		0.1315***	-0.1079***	0.5004***
		(0.03)	(0.04)	(0.19)
Distortionary taxes	0.2194**		0.0790***	
	(0.10)		(0.03)	
Non-distortionary taxes	0.1615***	0.1720***		
	(0.06)	(0.03)		
Error correction term	-0.0062*	-0.0232***	-0.0077	-0.0051**
	(0.00)	(0.01)	(0.01)	(0.00)
Short-run effects (first difference)				
Investment ratio	0.0042***	0.0041***	0.0042***	0.0048***
	(0.00)	(0.00)	(0.00)	(0.00)
Labour growth	-0.0002	-0.0028	-0.0045	-0.0028
	(0.00)	(0.00)	(0.00)	(0.00)
Total expenditure	-0.0033**	-0.0034**	-0.0025	-0.0025
	(0.00)	(0.00)	(0.00)	(0.00)
Budget balance		-0.0010	0.0030	-0.0002
		(0.00)	(0.00)	(0.00)
Distortionary taxes	0.0072		0.0090*	
	(0.01)		(0.01)	
Non-distortionary taxes	-0.0005	-0.0036		
	(0.00)	(0.00)		
Log-likelihood	1191.82	1347.73	1194.65	1334.68
N	496	572	496	572
n_g	17	17	17	17

Notes: Standard errors in parentheses below parameters

***, **, * Statistical significance at 1%, 5% and 10% respectively

Instead, when increased total spending is financed by either budget deficit (Column (1)) or non-distortionary taxes (Column (3)), the long-run GDP per capital level might deteriorate. The adverse long-run effects on GDP per capita from budget deficit financing (at -0.2278) are greater than the effects from non-distortionary taxes financing (-0.0725).

As seen in Table 3-11, the estimated coefficient of budget surplus in Column (2) is positive, whereas that in Column (3) is negative. This implies that improving budget balance but simultaneously increasing distortionary taxes to finance additional spending has different impacts on GDP per capita than improving of budget balance but simultaneously increasing non-distortionary taxes.

The positive effects of gross capital formation on GDP are evident. The estimated coefficients of ∅ indicate speeds of convergence to equilibrium of around less than 2.3% per year. This implies that the effects of fiscal shock by permanent increases in total spending on the level of GDP per capita could be highly persistent in developing Sample 3 countries.

As stated earlier, we investigate the potential long-run impacts of public spending composition on GDP per capita by focussing on the specification in which changes in total public spending are implicitly financed by changes in the budget balance. To save space, the results for public expenditure composition in the tables present only the parameters for total public expenditure and the functional spending of interest.

As illustrated by Table 3-12, there is an evidence that an increase in the share of a particular type of spending could improve the level of per capita GDP in the long run for developing Sample 3 countries. This could be done through increases in the spending shares of healthcare and general public services. A 1% permanent increase in the share of general public services to total spending could improve the long-run GDP per capita level by 1.5%. A permanent increase in health spending has a more substantial favourable impact on long-run GDP (8.7%). In contrast, an adverse effect on long-run GDP per capita is found with defence spending (-5.5%) and education spending (-8.5%). Increases in the shares of transportation and communication, and social welfare do not have significant impacts on long-run GDP per capita. The low value of convergence rates again confirms the enduring effects of fiscal policy shock in

developing Sample 3 countries. The positive value of estimated error correction coefficient in Column (5) for the change in the share of health spending might suggest divergence from a long-run equilibrium relationship after fiscal change. As a result, it is important to take care when interpreting the enhancing effect of an increase in the share of health spending on long-run GDP in developing Sample 3 countries.

Table 3-12: PMG for developing Sample 3 countries using public expenditure composition

Estimation method	Pooled mean group estimates					
Dependent variable	Annual GDP per capita growth rate (**Δ**y)					
Implicit financing element	Budget surplus/ deficit					
Share of	GPS	DEF	TRC	EDU	HEA	SOC
	(1)	**(2)**	**(3)**	**(4)**	**(5)**	**(6)**
Regressor	**b/se**	**b/se**	**b/se**	**b/se**	**b/se**	**b/se**
Long-run effects						
Total expenditure	0.0064	-0.0171***	0.0249***	0.0518*	0.0446***	0.0186**
	(0.01)	(0.00)	(0.01)	(0.03)	(0.01)	(0.01)
Expenditure share	0.0148***	-0.0553***	-0.0209	-0.0849**	0.0865***	-0.0090
	(0.00)	(0.01)	(0.01)	(0.04)	(0.02)	(0.01)
Error correction term	-0.0197	-0.0800***	-0.0120	-0.0046	0.0032	-0.0165
	(0.02)	(0.03)	(0.02)	(0.01)	(0.03)	(0.02)
Short-run effects (first difference)						
Total expenditure	-0.0035**	-0.0025	-0.0038**	-0.0051***	-0.0031	-0.0043***
	(0.00)	(0.00)	(0.00)	(0.00)	(0.00)	(0.00)
Expenditure share	-0.0005	0.0035	-0.0017	-0.0039	-0.0001	-0.0012
	(0.00)	(0.00)	(0.00)	(0.00)	(0.00)	(0.00)
Log-likelihood	1155.63	1176.05	1155.80	1158.78	1152.41	1161.76
N	479	480	473	475	470	474
n_g	17	17	17	17	17	17

Notes: Standard errors in parentheses below parameters

***, **, * Statistical significance at 1%, 5% and 10% respectively

3.2.5.2 High-income OECD Sample 3 countries (1972-2012)

Looking at the total public expenditure effects on the 21 high-income OECD Sample 3 countries presented in Table 3-13, the only case in which an increase in public spending enhances the long-run level of GDP per capita is when the increase is financed by non-distortionary taxes. The long-run GDP per capita level could be raised by 1.2% with a 1% permanent increase in total spending as a share of GDP when financed by non-distortionary taxation.

Table 3-13: PMG for high-income OECD Sample 3 countries testing for total public expenditure effects

Estimation method	Pooled mean group estimates			
Dependent variable	Annual GDP per capita growth rate (**Δ**y)			
Implicit financing element	SURBP	DISTAX	TGS	DISTAX, TGS
	(1)	**(2)**	**(3)**	**(4)**
Regressor	**b/se**	**b/se**	**b/se**	**b/se**
Long-run effects				
Investment ratio	0.0216***	0.0176***	0.0515***	0.0521***
	(0.01)	(0.01)	(0.01)	(0.02)
Labour growth	0.0379*	0.0382**	0.0165	0.0347
	(0.02)	(0.02)	(0.02)	(0.04)
Total expenditure	-0.0264***	-0.0414***	0.0122**	-0.0547***
	(0.01)	(0.01)	(0.01)	(0.01)
Budget balance		-0.0252***	0.0471***	-0.0162
		(0.01)	(0.01)	(0.02)
Distortionary taxes	-0.0111		-0.0692***	
	(0.01)		(0.01)	
Non-distortionary taxes	0.1578***	0.1717***		
	(0.01)	(0.01)		
Error correction term	-0.0295***	-0.0344***	-0.0255***	-0.0202***
	(0.01)	(0.01)	(0.01)	(0.00)
Short-run effects (first difference)				
Investment ratio	0.0059***	0.0060***	0.0057***	0.0059***
	(0.00)	(0.00)	(0.00)	(0.00)
Labour growth	0.0008	0.0008	0.0012	0.0013*
	(0.00)	(0.00)	(0.00)	(0.00)
Total expenditure	-0.0031***	-0.0024**	-0.0052***	-0.0032***
	(0.00)	(0.00)	(0.00)	(0.00)
Budget balance		0.0010*	-0.0022*	0.0001
		(0.00)	(0.00)	(0.00)
Distortionary taxes	0.0017*		0.0039**	
	(0.00)		(0.00)	
Non-distortionary taxes	-0.0076***	-0.0090***		
	(0.00)	(0.00)		
Log-likelihood	2153.14	2326.02	2128.86	2264.77
N	751	812	751	812
n_g	21	21	21	21

Notes: Standard errors in parentheses below parameters

***, **, * Statistical significance at 1%, 5% and 10% respectively

An increase in total spending using financing methods related to budget deficit or distortionary taxation has a harmful effect on long-run GDP per capita levels in high-income OECD Sample 3 countries. The long-run GDP impact is most damaging when the increased total spending is funded by a combination of distortionary and non-distortionary taxation (-5.5%). As also seen in the results for developing Sample 3 countries, the speeds of convergence to

equilibrium are low, at around 2.0% to 3.4% per year. The effect of fiscal policy shock could be long-lasting in high-income OECD Sample 3 countries. The convergence rates are higher than in developing Sample 3 countries.

Table 3-14: PMG for high-income OECD Sample 3 countries using public expenditure composition

Estimation method	Pooled mean group estimates					
Dependent variable	Annual GDP per capita growth rate (***Δ***y)					
Implicit financing element	Budget surplus/ deficit					
Share of	GPS	DEF	TRC	EDU	HEA	SOC
	(1)	**(2)**	**(3)**	**(4)**	**(5)**	**(6)**
Regressor	**b/se**	**b/se**	**b/se**	**b/se**	**b/se**	**b/se**
Long-run effects						
Total expenditure	-0.0224***	-0.0266***	-0.0206***	-0.0255***	-0.0272***	-0.0288***
	(0.01)	(0.01)	(0.01)	(0.01)	(0.01)	(0.01)
Expenditure share	-0.0217***	0.0075	-0.0161	0.1587***	0.0019	-0.0065
	(0.01)	(0.02)	(0.01)	(0.03)	(0.01)	(0.00)
Error correction term	-0.0336***	-0.0308***	-0.0298***	-0.0191***	-0.0293***	-0.0308***
	(0.01)	(0.01)	(0.01)	(0.01)	(0.01)	(0.01)
Short-run effects (first difference)						
Total expenditure	-0.0029***	-0.0032***	-0.0030***	-0.0034***	-0.0032***	-0.0035***
	(0.00)	(0.00)	(0.00)	(0.00)	(0.00)	(0.00)
Expenditure share	0.0025***	-0.0246	0.0002	-0.0037	-0.0001	-0.0026***
	(0.00)	(0.02)	(0.00)	(0.00)	(0.00)	(0.00)
Log-likelihood	2158.86	2104.88	2121.31	2143.91	2155.40	2174.53
N	742	717	728	740	742	742
n_g	21	21	21	21	21	21

Notes: Standard errors in parentheses below parameters

***, **, * Statistical significance at 1%, 5% and 10% respectively

The results of the functional spending analysis of high-income OECD Sample 3 countries in Table 3-14 suggest that in the long term, increases in the share of spending for general public services will deteriorate the GDP per capita level. On the other hand, more could be spent on education relative to other types of spending while increasing the long-term level of GDP per capita, given the ratio of total spending to GDP. A 1% permanent increase in the share of spending for education will raise the long-run GDP per capita level by 15.9% in high-income OECD Sample 3 countries. This strong positive impact may need further verification. The convergence rates are similar to those in the analysis of change in total public spending.

3.2.6 Breakdown of non-distortionary taxes for high-income OECD Sample 3 countries

Because financing from non-distortionary taxes (TGS) for additional public expenditure can enhance GDP per capita level in the long run for high-income OECD Sample 3 countries, we also consider which kind of non-distortionary tax financing is conducive to increasing long-run GDP levels. As in the anlysis in Subsection 3.2.5, the ARDL(1,1) model is applied to the pooled mean group (PMG) estimates, including the first difference of all control variables when considering short-run effects. The implicit financing element of non-distortionary taxes consists of three key components: general taxes on goods and services (GTGS); excise taxes on goods and services (ETGS); and other non-distortionary taxes (OTGS).

Figure 3-4 presents the 10-year unweighted averages of the composition of non-distortionary taxes in high-income OECD Sample 3 countries. The composition of non-distortionary taxes for high-income OECD Sample 3 countries between 1972 and 2012 comprises, on average, 59.5% of general taxes on goods and services, 31.0% of excise taxes and 9.5% of other non-distortionary taxes. The proportion of general taxes has increased over time. On the contrary, excise taxes and other non-distortionary taxes have steadily decreased.

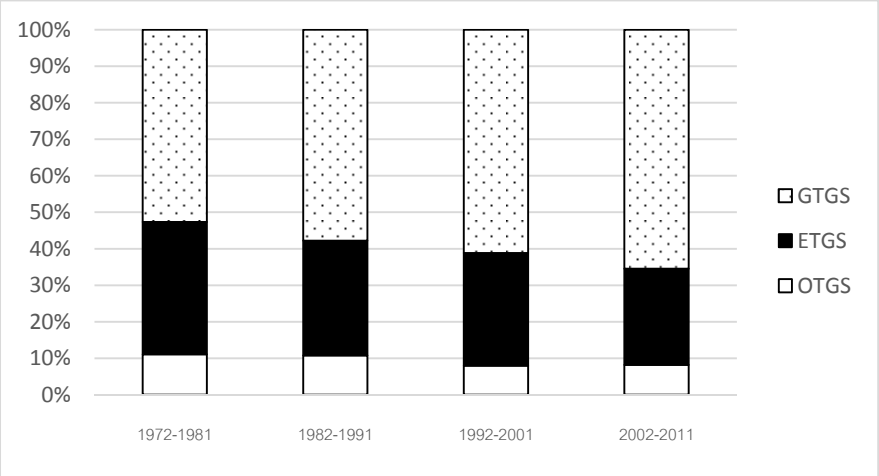


Figure 3-4: Unweighted 10-year averages of non-distortionary taxes composition for high-income OECD Sample 3 countries

The specification of equations is similar to that in the analysis in Subsection 3.2.5 for long-run GDP impacts of the changes in total public spending using non-distortionary taxes as a source of funding (Equation (8)). The implicit financing elements considered in this subsection include general taxes, excise taxes and other non-distortionary taxes. They are all included additionally and separately in the equations as a share of GDP complementing Equation (8). The descriptions of variables are listed in Table 3-15.

Table 3-15: List of variables for the composition of non-distortionary taxation

Variables	Description of the variables
gtgs_gdp	General taxes on goods and services (% of GDP)
etgs_gdp	Excise taxes on goods and services (% of GDP)
otgs_gdp	Other non-distortionary taxes (% of GDP)

The error correction form equations can be specified by Equation (11) to Equation (13) according to implicit financing elements: general taxes in Equation (11), excise taxes in Equation (12) and other non-distortionary taxes in Equation (13). The estimates in Table 3-16 also include the results of Equation (8) in Column (1) in order to compare the financing of non-distortionary taxation and its constituents.

$$\begin{aligned}\Delta y_{i,t} = \emptyset_i\big(y_{i,t-1} - \beta_1 K_t - \beta_2 LG_t - \beta_3 tot\_gdp_t - \beta_4 SURBP_t - \beta_5 distax\_gdp_t \\ - \beta_6 etgs\_gdp_t - \beta_7 otgs\_gdp_t\big) + \beta_{1i}^{*}\Delta K_{i,t} + \beta_{2i}^{*}\Delta LG_{i,t} + \beta_{3i}^{*}\Delta tot\_gdp_{i,t} \\ + \beta_{4i}^{*}\Delta SURBP_{i,t} + \beta_{5i}^{*}\Delta distax\_gdp_{i,t} + \beta_{6i}^{*}\Delta etgs\_gdp_{i,t} + \beta_{7i}^{*}\Delta otgs\_gdp_{i,t} \\ + \mu_i + \varepsilon_{i,t}\end{aligned} \tag{11}$$

$$\begin{aligned}\Delta y_{i,t} = \emptyset_i\big(y_{i,t-1} - \beta_1 K_t - \beta_2 LG_t - \beta_3 tot\_gdp_t - \beta_4 SURBP_t - \beta_5 distax\_gdp_t \\ - \beta_6 gtgs\_gdp_t - \beta_7 otgs\_gdp_t\big) + \beta_{1i}^{*}\Delta K_{i,t} + \beta_{2i}^{*}\Delta LG_{i,t} + \beta_{3i}^{*}\Delta tot\_gdp_{i,t} \\ + \beta_{4i}^{*}\Delta SURBP_{i,t} + \beta_{5i}^{*}\Delta distax\_gdp_{i,t} + \beta_{6i}^{*}\Delta gtgs\_gdp_{i,t} + \beta_{7i}^{*}\Delta otgs\_gdp_{i,t} \\ + \mu_i + \varepsilon_{i,t}\end{aligned} \tag{12}$$

$$\Delta y_{i,t} = \emptyset_i(y_{i,t-1} - \beta_1 K_t - \beta_2 LG_t - \beta_3 tot\_gdp_t - \beta_4 SURBP_t - \beta_5 distax\_gdp_t - \beta_6 gtgs\_gdp_t - \beta_7 etgs\_gdp_t) + \beta_{1i}^* \Delta K_{i,t} + \beta_{2i}^* \Delta LG_{i,t} + \beta_{3i}^* \Delta tot\_gdp_{i,t} + \beta_{4i}^* \Delta SURBP_{i,t} + \beta_{5i}^* \Delta distax\_gdp_{i,t} + \beta_{6i}^* \Delta gtgs\_gdp_{i,t} + \beta_{7i}^* \Delta etgs\_gdp_{i,t} + \mu_i + \varepsilon_{i,t} \quad (13)$$

As seen in Table 3-16, the results from the PMG estimation for high-income OECD Sample 3 countries show that the positive impact on GDP per capita from additional public spending only occurs when it is financed by an increase in excise taxes. A 1% of GDP increase in total spending financed by excise taxes will raise long-run GDP per capita by 4.4% (Column (3)). This positive effect is higher than the 1.2% increase from non-distortionary taxes financing at aggregate level shown in Column (1). While financing incremental spending by using other non-distortionary taxes has a negative impact on the level of GDP per capita in the long run, an increase in total spending financed by general taxes does not have significant effect on the long-run GDP per capita level.

Our analysis demonstrates that the favourable impact of changes in total spending through financing by non-distortionary taxes is highly influenced by the role played by excise taxes. The speed of adjustment to equilibrium long-run relationship is consistent with the findings in Subsection 3.2.5. The convergence rates are around 1.7% to 3.3% per year.

Table 3-16: PMG for high-income OECD Sample 3 countries with broad categories of fiscal variables (non-distortionary taxes breakdown)

Estimation method	Pooled mean group estimates			
Dependent variable	Annual GDP per capita growth rate (***Δ***y)			
Implicit financing element	TGS	GTGS	ETGS	OTGS
	(1)	**(2)**	**(3)**	**(4)**
Regressor	**b/se**	**b/se**	**b/se**	**b/se**
Long-run effects				
Investment ratio	0.0515***	0.0229**	0.0063	0.0125
	(0.01)	(0.01)	(0.00)	(0.01)
Labour growth	0.0165	0.0790***	0.0056	0.0561
	(0.02)	(0.03)	(0.01)	(0.04)
Total expenditure	0.0122**	-0.0077	0.0443***	-0.1556***
	(0.01)	(0.01)	(0.00)	(0.02)
Budget balance	0.0471***	0.0269**	0.0651***	-0.0762***
	(0.01)	(0.01)	(0.01)	(0.03)
Distortionary taxes	-0.0692***	-0.0293**	-0.0595***	0.0535**
	(0.01)	(0.01)	(0.01)	(0.02)
General taxes			0.0329*	0.2733***
			(0.02)	(0.05)
Excise taxes		0.2921***		0.4369***
		(0.05)		(0.08)
Other taxes		-0.0087	0.1041***	
		(0.05)	(0.02)	
Error correction term	-0.0255***	-0.0196***	-0.0331**	-0.0169***
	(0.01)	(0.01)	(0.01)	(0.00)
Short-run effects (first difference)				
Investment ratio	0.0057***	0.0059***	0.0059***	0.0062***
	(0.00)	(0.00)	(0.00)	(0.00)
Labour growth	0.0012	0.0010	0.0016*	0.0007
	(0.00)	(0.00)	(0.00)	(0.00)
Total expenditure	-0.0052***	-0.0050***	-0.0052***	-0.0019
	(0.00)	(0.00)	(0.00)	(0.00)
Budget balance	-0.0022*	-0.0015	-0.0017	0.0015*
	(0.00)	(0.00)	(0.00)	(0.00)
Distortionary taxes	0.0039**	0.0033*	0.0026	-0.0003
	(0.00)	(0.00)	(0.00)	(0.00)
General taxes			-0.0062**	-0.0059**
			(0.00)	(0.00)
Excise taxes		-0.0096*		-0.0115**
		(0.01)		(0.00)
Other taxes		-0.0108	-0.0235	
		(0.01)	(0.02)	
Log-likelihood	2128.8558	2138.6254	2145.9160	2140.5469
N	751	731	731	736
n_g	21	21	21	21

Notes: Standard errors in parentheses below parameters

***, **, * Statistical significance at 1%, 5% and 10% respectively

3.2.7 Comparison with the results of Gemmell et al. (2016)

The literature investigating impacts of fiscal changes on long-run GDP levels focusses on government revenues. To the best of my knowledge, Gemmell et al. (2016) is the only study that can be directly compared with our analysis of the effects of changes in government expenditure on the long-run GDP per capita.

While Gemmell et al. (2016) include data for 17 OECD countries between 1970 and 2008, we extend this to include data for 21 OECD countries between 1972 and 2012. It must be noted that their data is not nested in our sample. 14 out of 17 countries in their sample are included in our high-income OECD Sample 3 countries, as shown in Table 3-7.

Firstly, we compare the estimates for the long-run level of GDP impacts of changes in total government spending. Our results for high-income OECD Sample 3 countries have shown that increasing total spending only has a favourable effect on the long-run GDP per capita level when the spending is financed by non-distortionary taxation. This finding is consistent with that of Gemmell et al. (2016). While they have found that a 1% permanent increase in total spending as a share of GDP financed by non-distortionary taxes will raise the long-run GDP per capita level by 2.0%, our analysis has shown that the impact is positive, but somewhat lower, at 1.2%. The speed of convergence to equilibrium in both studies is similarly low, at around 3.9% to 9.2% a year in Gemmell et al. (2016) and 2.0% to 3.4% in our study. Our results indicate that this may persist longer than Gemmell et al. (2016) suggest.

Secondly, we look at the long-run GDP impacts of shifting spending from the remaining categories into particular functions. Gemmell et al. (2016) find evidence of potentially positive GDP effects from changes in transportation and communication spending, and education spending. We also find that changing the share of education spending can have a favourable effect, although the impact from changing the share of transporation and communication spending is insignificant. This might demonstrate that the GDP-enhancing effect of an increase in the share of transportation and communication spending reported in Gemmell et al. (2016) is not robust when additional high-income OECD countries are included. Furthermore, their results might be specific to the period

of 1970 to 2008. In contrast, the positive impact on long-run GDP per capita from a change in education spending share is reaffirmed. However, the GDP-promoting effect of 15.9% in our study might be overstated, compared with the 2.0% in Gemmell et al. (2016). Both studies observe significant negative long-run associations between GDP and share of general public services spending.

3.3 Concluding remarks

In this chapter, we investigated the relationship between public expenditure and the sizes of economies in two different circumstances. First, in Study 2 with groups of Sample 2 countries, the permanent growth impacts of fiscal changes in the public-policy endogenous growth model are investigated using broad categories of fiscal variables, namely productive expenditure, non-productive expenditure, distortionary taxes and non-distortionary taxes. The effects on growth are considered under the government budget constraint, according to Kneller et al.'s (1999) theoretical definitions, using several implicit financing elements. Secondly, we investigated the relationship between public spending and long-run GDP per capita level within the framework proposed by Gemmell et al. (2016) in Study 3 using the Sample 3 groups of countries.

With regard to government budget constraint in Study 2, the evidence for an increase in productive expenditure being conducive to growth exists only for high-income OECD Sample 2 countries. This applies to additional spending financed solely by reducing non-productive expenditure or by combining this with an increase in non-distortionary taxes. The growth-deteriorating effect of distortionary taxes is obvious across countries. These findings for productive expenditure and distortionary taxes in high-income OECD Sample 2 countries are consistent with those of Kneller et al (1999).

When examining the relationship between public spending and the level of long-run GDP per capita when the first differences of control variables are all included in short-run effects in Study 3, we see that an increase in total spending which is financed by non-distortionary taxes only enhances the level of GDP per capita in the case of high-income OECD Sample 3 countries. This is driven by excise taxes financing, in particular.

Given that total spending is level, increases in the shares of healthcare and general public services spending can improve the levels of GDP per capita in developing Sample 3 countries. On the other hand, increasing the share of education spending in a high-income OECD Sample 3 country is conducive to increasing the level of GDP per capita. This result differs from those of Gemmell et al. (2016); they found that a positive long-run effect on output level could be achieved in their OECD countries by reallocating total spending towards both transportation and communication, and education spending. This might imply that the favourable GDP impacts of changes to the transporation and communication spending share for OECD countries found by Gemmell et al. (2016) are not robust.

The speed of adjustment to the long-run equilibrium relationship in our analysis in Study 3 is exceptionally low for both developing Sample 3 countries and high-income OECD Sample 3 countries. The impacts of fiscal changes on GDP can be extremely persistent. This also extends to transitory growth effects, which could also persist during this transition.

It is worth noting that the ARDL(1,1) model used in Study 3 excludes the possibility that fiscal changes on GDP per capita have longer, persistent effects which could be captured by, for example, the second lag. In other words, endogenity might exist within our estimated parameters. However, we find that second difference is rarely required for the regressors using time series data to identify ARDL lag structure. Hence, there is reason to believe that endogeneity is not a major concern in our study.

In summary, our study shows that increasing revenue through distortionary taxes should be avoided, since it reduces the rate of economic growth. Moreover, the growth impacts of fiscal changes vary by different implicit financing elements.

Governments of high-income OECD countries may be able to improve GDP per capita levels in the long run by using non-distortionary taxes to increase total spending. Changing the composition of public spending while holding the total spending constant, could also enhance the long-run GDP per capita level. In high-income OECD countries, this could be done by increasing the proportion of education spending. In developing countries, this could be

done by increasing in the share of general public services or healthcare spending.

Chapter 4: Telecommunication infrastructure and economic development

The evidence of positive growth impacts from an increase in transportation and communication spending in both developing and high-income countries in Chapter 2 helps to improve our understanding of the role played by telecommunication infrastructure in economic development.

In this chapter, we further investigate the relationship between telecommunication infrastructure and aggregate output by particularly looking at the output contribution of two different types of communication technologies: fixed telephones and mobile phones. This will be attempted by using a simultaneous-equations based estimation strategy. There are three main objectives in using this method. First, our study takes a structural approach to the estimation of fixed telephones and mobile phones' contributions in a production function type setting. We do this by establishing cointegrating relationships between variables to reflect the underlying theoretical structure. Second, the endogeneity issue is addressed by estimating a system of equations, using three-stage least squares (3SLS). Third, non-linear effects of mobile phones and fixed telephones on production are tested.

Table 4-1: List of Sample 4 countries for the analysis of telecommunication and economic development (Study 4)

Developing countries		**High-income OECD countries**	
Brazil	Morocco	Australia	Italy
Costa Rica	Peru	Austria	Japan
Egypt.	South Africa	Belgium	Korea, Rep.
India	Syrian Arab Republic	Canada	Luxembourg
Indonesia	Thailand	Chile	Netherlands
Lesotho	Tunisia	Denmark	New Zealand
Malaysia	Turkey	Finland	Norway
Mauritius	Venezuela	France	Portugal
Mexico		Germany	Spain
		Greece	Sweden
		Iceland	Switzerland
		Ireland	United Kingdom
		Israel	United States

In the following analysis, 26 high-income OECD and 17 developing countries are examined in two different periods of time: 1975-1990 and 1990-2012. The list of countries is shown in Table 4-1. These groups will be referred to as Sample 4.

4.1 Introduction

The telecommunication industry has grown significantly over the past few decades. The share of telecommunication revenue to GDP in high-income OECD countries increased from 1.29% in 1975 to 2.23% in 2012.[4] The figures for developing countries increased even more: from 0.67% to 3.08% of GDP.[5] Fixed telephone subscriptions in high-income OECD countries increased significantly between 1975 and 2000; however, the level of penetration has gradually decreased since then.[6] The adoption of fixed telephones in developing countries was much slower and reached its highest penetration in 2009. Mobile-cellular telephone infrastructure was launched in the 1980s; however, the usage of mobiles has accelerated quickly, surpassing fixed telephone subscriptions in the 2000s in both high-income OECD and developing countries.[7]

The expansion of the telecommunication industry is related to increases in economic activities. Telecommunication investment leads to economic development for several reasons as discussed by Roller and Waverman (2001). Firstly, it leads to higher consumption of telecommunication final outputs and intermediate goods for providing telecommunication services. This would also increase demand for goods and services used in telecommunication infrastructure production. Secondly, the economic returns are higher than the return from telecommunication investment itself, in part because improved communication makes production more efficient and improves business operation. Furthermore, with network externalities, the output dividend from telecommunication investment could be non-linear. It is interesting to note that increasing returns at a higher level of telecommunication infrastructure may

[4] There are 26 high-income OECD countries included in this study. (see Table 4-1)
[5] There are 17 developing countries included in this study. (see Table 4-1)
[6] In this study and various studies, fixed telephone can also be referred to as fixed-line, main line, access line, telephone line and main telephone.
[7] Mobile phone may be referred to as mobile-cellular and cellular.

exist. This is different from the diminishing returns from other types of infrastructure. Consequently, it is important to understand the impact of telecommunication investment at the macroeconomic level.

The study of the relationship between telecommunication infrastructure and economic development potentially suffers from the problems of reverse causality and spurious correlation as pointed out in Roller and Waverman (2001). Using a simultaneous model to investigate the relationship between telecommunication investment and economic growth can resolve simultaneity. Controlling for country specific effects will lessen the problem of spurious correlations. By doing this, the heterogeneity or individual effects which may be unobserved are taken to be constant over time (Greene, 2012).

The next section reviews related literature on telecommunications and economic development.

4.2 Review of literature on telecommunications and economic development

The level of economic development varies across countries because of differences in long-term economic growth rates. However, the cause of the unequal rates of growth has not been precisely verified (Norton, 1992). In order to identify a major reason for the unequal rates, the growth of the economy has been linked with telecommunications by recent empirical and theoretical literature; for example, a significantly positive relationship between telecommunication infrastructure and growth was found by Datta and Agarwal (2004). Another example is an earlier study conducted by Norton (1992) in which the relationship between transaction costs, telecommunications, and economic growth was identified.

Understanding the development of the previous literature on telecommunication and economic development is an essential part of explaining the disparities in economic growth rates across countries. Therefore, the similarities and differences in the studies of the interaction between telecommunications and economic development have been systematically analysed.

4.2.1 Telecommunication infrastructure as a general purpose technology

Infrastructure is widely accepted to be an important factor contributing to economic growth. There are a number of elements that constitute infrastructure including roads, railway lines, electricity infrastructure and telephones. Considering a specific type of infrastructure can help us clearly understand the impact of infrastructure on economic development. In this study, we focus on telecommunication infrastructure.

Unlike most types of infrastructure, telecommunication is classified as general purpose technology (GPT). By this definition, telecommunication infrastructure consists of the three main characteristics described by Bresnahan and Trajtenberg (1995) as “pervasiveness, inherent potential for technical improvements, and innovational complementarities.” With these three special characteristics, telecommunications contribute a long-term positive impact on economic development.

However, the benefits gained from the introduction of GPT could come with costs incurred in the first stage of its adoption. This manifests itself in the example of the ICT (information and communication technology) sector. According to Basu and Fernald (2007), ICT investment could worsen Total Factor Productivity (TFP) since it directs the resources of the firms towards organizational change and the learning process for the new technology. This possibility of worsening TFP has influenced further research on the productivity loss and gain, as we can see from the work of Ristuccia and Solomou (2010) on electricity diffusion. Though it is not directly applied to telecommunication infrastructure, the results shown by Risuccia and Solomu (2010) raise a concern about the cost accompanying the economy-wide positive impact of telecommunication on growth when it is introduced. That initial phase might take much more time than what we would expect. Thus, this concern should be taken into account in future research.

4.2.2 Relationship between telecommunications and economic development

The relationship between telecommunications and economic development has been approached using several different frameworks. In this section, attention is given to two different classifications: the types of telecommunication infrastructure and the groups of countries which have been selected for studying the relationship between telecommunications and economic development.

The first type of telecommunication infrastructure that was widely studied is the telephone line (Datta & Agarwal, 2004; Hardy, 1980; Madden & Savage 1998; Norton, 1992). Later, researchers attempted to combine telephone lines and mobile-cellular together as "teledensity" to identify a link to economic development (Lam & Shiu, 2010; Sridhar & Sridhar, 2007; Zahra et al., 2008). Recent literature has shifted the focus of the study of telecommunication infrastructure to broadband penetration (Atif et al., 2012; Czernich et al., 2011; Koutroumpis, 2009). Some studies consider different types of information and communication technology (ICT). While Vu (2011) examines the growth effects of ICT penetration by separately considering the penetration rates of personal computers, mobile phones and internet users, Jacobsen (2003) uses both main lines and stock of telecommunication infrastructure including; main lines, mobile phones and personal computers, to investigate the relationship between telecommunications and economic development. As telecommunication technology advances, it is clear that the variables for telecommunication infrastructure selected by researchers have also evolved accordingly. However, the problem of unavailability of cross-country data is still a main issue that most studies need to take into account especially for developing countries where a new telecommunication technology might have been adopted recently.

Focussing on the group of countries as shown in Table 4-2, the studies of telecommunication infrastructure and economic development have been highly concentrated on high-income countries. Early research focussed on identifying the linkage of these two factors in high-income OECD countries (Datta & Agarwal, 2004; Roller & Waverman, 2001). There have been a few attempts to explore similar relationships in developing countries. Sridhar and

Sridhar (2007) studied the linkage between telephone penetration and economic growth in developing countries, whereas Madden and Savage (1998) considered the relationship of telecommunication investment and growth in CEE (Central and Eastern Europe) countries. A few studies compare the growth impacts of telecommunications between developing and developed countries (Dedrick et al., 2013; Dimelis & Papaioannou, 2010; Jacobsen, 2003).

Table 4-2: List of literature studying the relationship between telecommunications and economic development

Group of countries/ country specific	**Authors**
OECD countries	Roller & Waverman (2001) Datta & Agarwal (2004) Koutroumpis (2009) Czernich et al. (2011) Atif et al. (2012)
Developed and developing countries together	Hardy (1980) Norton (1992) Zahra et al. (2008) Lam & Shiu (2010) Gruber & Koutroumpis (2011) Vu (2011)
Developed and developing countries separately	Jacobsen (2003) Dimelis & Papaioannou (2010) Dedrick et al. (2013)
Developing countries	Waverman et al. (2005) Sridhar & Sridhar (2007)
Central and Eastern Europe	Madden & Savage (1998)
China	Ding et al. (2008)
United States	Greenstein & Spilller (1995) Yilmaz & Dinc (2002) Crandall et al. (2007) Gillett et al. (2007)

4.2.3 Measurement for telecommunications

The variables used to measure telecommunications in the studies of the relationship between telecommunication and economic development vary across time and the groups of countries being studied. These measures can be

broadly classified into two groups as shown in Table 4-3. The first group emphasises deployment of telecommunication infrastructure while the other concerns capital stock and investment in telecommunication. Different measurements are applied to all types of telecommunication infrastructure.

Table 4-3: List of telecommunication variables found in related studies

Telecommunication variables	Description	Authors
Telecommunication deployment		
Radios	Radios per 1,000 people at time t-1	Hardy (1980)
Telephone lines	Telephones per million people at time t-1	Hardy (1980)
	Access lines per 100 inhabitants	Norton (1992)
	Main lines per 100 inhabitants	Madden & Savage (1998)
	Main lines per capita	Roller & Waverman (2001)
	Penetration rate per capita of main telephone lines	Jacobsen (2003)
	Access lines per 100 inhabitants	Datta & Agarwal (2004)
	Main telephones per 100 inhabitants	Sridhar & Sridhar (2007)
	Number of telephones per capita	Ding et al. (2008)
	Fixed-line penetration	Gruber & Koutroumpis (2011)
	Fixed telephone subscriptions per 100 inhabitants	Atif et al. (2012)
Cellular penetration	Cellular phone subscribers per capita	Jacobsen (2003)
	Mobile telecoms penetration rate	Waverman et al. (2005)
	Number of cellular subscribers per 100 inhabitants	Sridhar & Sridhar (2007)
	Mobile phone penetration % of population	Gruber & Koutroumpis (2011)
	Penetration per 100 inhabitants of mobile phones	Vu (2011)
	Cellular penetration in percentages	Dedrick et al. (2013)
Teledensity	Number of fixed-line and mobile phone subscribers per 100 persons	Sridhar & Sridhar (2007)
	Number of fixed-line and mobile phone subscribers per 100 persons	Lam & Shiu (2010)
Squared telephone lines	The square of access lines per 100 inhabitants	Datta & Agarwal (2004)
Squared mobile phone penetration	The quadratic term of penetration per 100 inhabitants of mobile phones	Vu (2011)

Telecommunication variables	Description	Authors
Waiting list for main lines	Waiting list for main lines per capita Waiting list for main lines per capita Waiting list for main lines per 100 population	Roller & Waverman (2001) Jacobsen (2003) Sridhar & Sridhar (2007)
Change in fixed-line penetration rate	Growth of main line penetration Annual change in fixed-line penetration rate	Sridhar & Sridhar (2007) Lam & Shiu (2010)
Change in mobile phone penetration rate	Growth of cellular penetration Annual change in mobile phone penetration rate	Sridhar & Sridhar (2007) Lam & Shiu (2010)
Growth of total telecom	Growth of the summation of main line and cellular penetration	Sridhar & Sridhar (2007)
Price of telephone service	Price of telephone service in 1985 USD measured as service revenue per main line Telephone revenue per mainline, constant USD	Roller & Waverman (2001) Jacobsen (2003)
Personal computers	Penetration rate per capita of personal computers Penetration per 100 inhabitants of personal computers	Jacobsen (2003) Vu (2011)
Squared personal computer penetration	The quadratic term of penetration per 100 inhabitants of personal computers	Vu (2011)
Internet penetration	Penetration per 100 inhabitants of internet users Internet penetration in percentages	Vu (2011) Dedrick et al. (2013)
Squared internet user penetration	The quadratic term of penetration per 100 inhabitants of internet users	Vu (2011)
Broadband penetration	Total number of broadband subscribers per 100 inhabitants The share of population subscribed to broadband Broadband connection excluding mobile broadband	Koutroumpis (2009) Czernich et al. (2011) Atif et al. (2012)
Broadband introduction	First emergence of broadband Years since broadband introduction	Czernich et al. (2011) Czernich et al. (2011)
Broadband per capita	Broadband lines/ population	Crandall et al. (2007)
Broadband price		Koutroumpis (2009)
Herfindahl Index	The sum of squares of broadband connections per platform divided by the square of the total number of broadband connections	Koutroumpis (2009)
Telecommunication Infrastructure Index	Index of teledensity and number of internet users	Zahra et al. (2008)

Telecommunication variables	Description	Authors
Telecommunication Infrastructure Index squared	The square of Index of teledensity and number of internet users	Zahra et al. (2008)
Voice telephone penetration		Czernich et al. (2011)
Cable TV penetration		Czernich et al. (2011)
FIBRE	Fibre optic deployment at the company level	Greenstein & Spiller (1995)
Telecommunication stock and investment		
IT capital stock	Telecommunication capital stock Telecommunication capital stock	Yilmaz & Dinc (2002) Dedrick et al. (2013)
Broadband investment	Stock of telecommunication investment	Koutroumpis (2009)
ICT investment	Growth rate of ICT capital per worker	Dimelis & Papaioannou (2010)
Telecommunication investment	Share of telecommunication investment in GDP Investment in telecom infrastructure in billion 1985 USD Annual telecommunication investment in billion 1995 USD	Madden & Savage (1998) Roller & Waverman (2001) Jacobsen (2003)

4.2.3.1 Measuring telecommunication deployment

There are three aspects of telecommunication deployment identified by the literature survey which are introduction of telecommunication service, telecommunication penetration and the price of telecommunication.

Firstly, the introduction of telecommunication service is used by Czernich et al. (2011) where broadband introduction is a dummy variable.

Secondly, penetration is used to quantify how widely the service of a particular telecommunication feature has been utilised by the population in a country. The following presents measure for penetration in different forms.

1.) Penetration per 100 inhabitants

Penetration per 100 inhabitants is the measure that has been widely used across different types of telecommunication infrastructure as follows:

(1.1) Main lines or fixed-lines per 100 inhabitants is the earliest example and it has been used recurrently.

(1.2) The penetration of mobile-cellular per 100 inhabitants is used in more recent literature.

(1.3) A few studies combine both figures together; Sridhar and Sridhar (2007) and Lam and Shiu (2010) use teledensity in terms of the number of fixed-line and mobile phone subscribers per 100 inhabitants.

(1.4) The waiting list for main line subscribers also appears in Roller and Waverman (2001) and Sridhar and Sridhar (2007).

(1.5) Other types of telecommunication infrastructure are radios (Hardy, 1980), personal computers, internet users, broadband, voice telephony and cable TV. They are measured as fractions per 100 inhabitants.

2.) Penetration per capita

Instead of measuring by using penetration per 100 inhabitants, the reach of the service can be measured against each individual or in per capita terms. This has appeared in some cases of main line subscribers, waiting list of main line subscribers, personal computers and broadband lines.

3.) Penetration in percentage terms

The percentage term is another variable for measuring the penetration rate of a population as a whole. Dedrick et al. (2013) used cellular penetration and internet penetration in percentages as measurements of the telecommunication variable.

4.) The square of penetration per 100 inhabitants

The square of access lines per 100 inhabitants is one of the measures for telecommunication used by Datta and Agarwal (2004). The square terms of mobile phones, personal computers and internet users per 100 inhabitants are used in Vu (2011).

5.) Change in penetration per 100 inhabitants

The rate of change in penetration for main line and cellular and the summation of both main line and cellular have been used in several studies to identify the relationship between telecommunication and growth.

Lastly, the prices of the telecommunication services appeared in some of the literature, especially in simultaneous equations of demand and supply (Gruber & Koutroumpis, 2011; Roller & Waverman, 2001; Sridhar & Sridhar, 2007). Revenue per subscription is used as a proxy of price in Roller and Waverman (2001) and Jacobsen (2003).

4.2.3.2 Measuring telecommunication stock and investment

Stock and investment in telecommunications are the indicators of the availability of the telecommunication services. In terms of stock, telecommunication capital is a representative of the physical availability of the services. On the other hand, telecommunication investment determines the change in capital stock of telecommunication.

Telecommunication capital stock is measured by IT capital in Yilmaz and Dinc (2002) and Dedrick et al. (2013). This measure is not as widely used as telecommunication investment. Examples of the use of telecommunication investment can be found in studies by Roller and Waverman (2001) and Jacobsen (2003), where telecommunication investment is measured in billion USD, and Madden and Savage (1998) who use share of telecommunication in GDP. Alternatively, Koutroumpis (2009) chooses stock of telecommunication investment to represent broadband investment. Lastly, ICT investment is measured by the growth rate of ICT capital per worker in Dimelis and Papaioannou (2010).

Except for the two main measures of telecommunications that have been discussed previously, other indexes have been computed by authors specifically for the study of the relationship between telecommunication and economic development. For example, the Herfindahl Index is computed from broadband connections per platform in Koutroumpis (2009), telecommunication

infrastructure index is computed from teledensity and the number of internet users in Zahra et al. (2008).

Even though various measurements have been used for telecommunication variables, most of them are similar to the definitions generally used for penetration, capital and investment.

4.2.4 Conditioning variables in the study of telecommunications and economic development

Similar to the studies of the relationship between other variables and economic development, the study of the relationship between telecommunications and economic growth/output incorporates a wide range of macroeconomic variables. These control variables as shown in Table 4-4 can be classified broadly into economic indicators, social indicators and other relevant indicators.

Table 4-4: List of conditioning variables in related studies

Conditioning variables	Description	Authors
Economic conditions		
Growth $_{t-1}$	Lagged growth of real GDP per capita	Datta & Agarwal (2004)
	One-year lag of growth rate of real GDP per capita	Ding et al. (2008)
	Lagged growth of real GDP per capita	Zahra et al. (2008)
GDP $_{t-1}$	Gross domestic product per head at t-1	Hardy (1980)
	Lagged real GDP per capita	Datta & Agarwal (2004)
	Lagged real GDP per capita	Zahra et al. (2008)
	Lagged level of output per capita	Dimelis & Papaioannou (2010)
LGDP $_{t-1}$	Log of value of real GDP per capita in 1995 RMB	Ding et al. (2008)
Initial GDP	Initial year per capita income at 1975 prices	Norton (1992)
	Initial real GDP per capita in 1991	Madden & Savage (1998)
	GDP per capita in 1996	Czernich et al. (2011)
	GDP per capita at the initial year of subperiod	Vu (2011)
	GDP per capita at the initial year of subperiod squared	Vu (2011)

Conditioning variables	Description	Authors
SOE	Share of industrial output by state-owned enterprises in total industrial output	Ding et al. (2008)
Standard deviation of real output		Norton (1992)
Agriculture	Agriculture sector's value-added share in GDP	Vu (2011)
Money supply growth	Mean money supply growth	Norton (1992)
Standard deviation of money supply shocks		Norton (1992)
Growth of inflation	Mean growth of inflation rate	Norton (1992)
Government consumption	Mean growth of government spending to output	Norton (1992)
	Share of government consumption in GDP	Madden & Savage (1998)
	Share of government consumption in GDP	Datta & Agarwal (2004)
	Share of government consumption in GDP	Zahra et al. (2008)
	Government consumption %GDP	Dimelis & Papaioannou (2010)
Exports	Mean growth of exports	Norton (1992)
Imports	Net imports	Dedrick et al. (2013)
Trade openness	Total of exports and imports	Datta & Agarwal (2004)
	Openness of trade as a share of GDP	Dimelis & Papaioannou (2010)
	Merchandise trade to GDP ratio	Vu (2011)
Investment	Share of fixed investment in GDP	Madden & Savage (1998)
	Share of fixed investment in GDP	Datta & Agarwal (2004)
	Share of fixed investment in GDP	Ding et al. (2008)
	Log of capital formation to GDP	Czernich et al. (2011)
	Growth of capital formation to GDP	Czernich et al. (2011)
	Ratio of gross fixed capital formation to GDP	Vu (2011)
	Gross capital formation	Atif et al. (2012)
Lagged fixed investment	Share of fixed investment of previous year in current GDP	Zahra et al. (2008)
Public capital	Public capital stocks	Yilmaz & Dinc (2002)
Private capital	Private capital stocks	Yilmaz & Dinc (2002)
Stock of capital	Log of capital	Sridhar & Sridhar (2007)

Conditioning variables	Description	Authors
	Fixed stock of capital in million 2000 USD	Gruber & Koutroumpis (2011)
Non-IT capital stocks	Non-residential capital stock net of telecommunications capital	Roller & Wavermen (2001)
	Capital stock net of telecoms capital	Waverman et al. (2005)
	Non ICT stock of capital	Koutroumpis (2009)
	Non IT capital stocks	Dedrick et al. (2013)
Growth of domestic capital	Growth rate of domestic capital per worker	Dimelis & Papaioannou (2010)
Growth of foreign capital	Growth rate of foreign capital per worker	Dimelis & Papaioannou (2010)
FDI	Share of foreign direct investment divided by total fixed investment	Ding et al. (2008)
	Growth rate of foreign capital per worker	Dimelis & Papaioannou (2010)
	Foreign direct investment	Dedrick et al. (2013)
Social indicators		
Education	Share of college graduates in adult population	Crandall et al. (2007)
	Log of years of education	Czernich et al. (2011)
	Growth of years of education	Czernich et al. (2011)
	Gross secondary school enrolment rate	Vu (2011)
	Tertiary education as a proportion of the population aged 25 to 64	Atif et al. (2012)
	Tertiary education	Dedrick et al. (2013)
Human capital	Human capital measured by the average years of schooling for the population aged 6 and above	Ding et al. (2008)
Labour	Total labour force in millions	Roller & Waverman (2001)
	Total labour force in millions	Jacobsen (2003)
	Total labour force	Waverman et al. (2005)
	Log of labour	Sridhar & Sridhar (2007)
	Population aged 15-64 with full or part time work in thousands	Koutroumpis (2009)
	Labour (thousands people)	Gruber & Koutroumpis (2011)
	Labour hours	Dedrik et al. (2013)
Employment	Share of total employment to total population	Ding & Haynes (2006)
	Share of total employment to total population	Ding et al. (2008)
Growth of working age	Change in growth of working-age population	Czernich et al. (2011)

Conditioning variables	Description	Authors
population		
Urban population	Share of urban population to total population	Ding et al. (2008)
Population share	Share of the country in the world population	Vu (2011)
Population growth	Mean annual population growth	Norton (1992)
	Growth of population	Madden & Savage (1998)
	Growth of population	Datta & Agarwal (2004)
	Annual population growth rate	Ding & Haynes (2006)
	Annual population growth rate	Ding et al. (2008)
	Growth rate of population in low-income ,middle-income and high-income countries	Zahra et al. (2008)
Immigration	Immigration per million persons	Dedrick et al. (2013)
Other relevant indicators		
Transportation density	Transportation density as measured by the length of rail, highway and waterway networks per square kilometre	Ding & Haynes (2006)
	Transportation density as measured by the length of rail, highway and waterway networks per square kilometre	Ding et al. (2008)
Tax Climate Index	State Business Tax Climate Index	Crandall et al. (2007)
TI	Transparency Index	Dimelis & Papaioannou (2010)
Institution	The country's Rule of Law Index	Vu (2011)
BRCC	Dummy variable for Baltic States	Madden & Savage (1998)

4.2.4.1 Controlling economic conditions

Economic indicators appear repeatedly in the literature studying the relationship between economic development and telecommunication. This type of indicator can be classified into six categories which are economic outputs, monetary variables, fiscal variables, trade variables, capital and investment variables, and foreign direct investment.

1.) Economic outputs

As a control variable, output is typically measured in lagged terms or initial value. There are a few different measures of output in terms of its share and standard deviation.

(1.1) Lagged growth rate of real GDP per capita appears in the studies of Datta and Agarwal (2004), Ding et al. (2008) and Zahra et al. (2008).

(1.2) Lagged real GDP per capita is included in the model used in Datta and Agarwal (2004) and Zahra et al. (2008). This variable may appear in logarithmic form (Ding et al., 2008). Alternatively, Hardy (1980) used gross domestic product per head at time t-1.

(1.3) Initial GDP per capita is used frequently as a control variable. The choice of year selected by researchers as an initial period varies according to the specific time period. Vu (2011) also includes the quadratic term of intial GDP.

(1.4) Share of industrial output by state-owned enterprises is a different form of determining economic output which is used in Ding et al. (2008).

(1.5) Agriculture sector's value-added share in GDP is included in the study of Vu (2011).

(1.6) Standard deviation of real output is used by Norton (1992).

2.) Monetary variables

Three different values for monetary variables are used in Norton (1992) as follows:

(2.1) Mean of money supply growth

(2.2) Standard deviation of money supply shocks

(2.3) Growth of inflation rate

3.) Fiscal variables

Government spending is used as a fiscal variable in the group of control variables. There are two examples of measurements used in our list of literature as follows:

(3.1) Share of government consumption in GDP

(3.2) Mean growth of government spending to output.

4.) Trade variables

International trade is measured in three different forms as follows:

(4.1) Exports

(4.2) Imports

(4.3) Trade openness (the total value of exports and imports)

5.) Capital and investment variables

Capital and investment are significant contributors to economic development. The following are examples of variables used to represent them.

(5.1) Investment is measured as a share of fixed investment in GDP in Madden and Savage (1998), Datta and Agarwal (2004) and Ding et al. (2008).

(5.2) Lagged fixed investment is a share of fixed investment from the previous year in current GDP. (Zahra et al., 2008)

(5.3) Capital formation has been measured using different functional forms. While Atif et al. (2012) use level gross capital formation as a measure of investment, Vu (2011) includes the ratio of gross fixed capital formation to GDP. Sridhar and Sridhar (2007) use log of capital, whereas Czernich et al. (2011) use log of capital formation to GDP and growth of capital formation to GDP.

(5.4) Public and private capital stocks are used in Yilmaz and Dinc (2002).

(5.5) Non-IT capital stocks have also been measured in various forms. Non-residential capital stock net of telecommunications capital is used in Roller and Waverman (2001). Waverman et al. (2005) used total physical capital stock net of telecom capital. Non-ICT stock of capital is used in Koutroumpis (2009). Similarly, non-IT capital stock is used in Dedrick et al. (2013).

(5.6) Fixed stock of capital is used in Gruber and Koutroumpis (2011), while log of capital is found in Sridhar and Sridhar (2007).

(5.7) Growth of capital per worker is used in Dimelis and Papaioannou (2010).

6.) Foreign direct investment

The impact from external sector is controlled in several studies using foreign direct investment. (Dedrick et al., 2013; Dimelis & Papaioannou, 2010; Ding et al., 2008)

4.2.4.2 Controlling social impacts

Social indicators are also important in determining economic development. This group of indicators can be separated into human development and demographic variables.

1.) Human development

Education is an essential process for human development. The level of education attained by the population in a country is a justified measure for human development.

(1.1) Education in years is used in Czernich et al. (2011) in two different forms: log of years of education and growth of years of education.

(1.2) Education as a proportion of population is used in Atif et al. (2012) by measuring tertiary education as a proportion of the population aged 25 to 64.

(1.3) Gross secondary school enrolment is used in Vu (2011).

2.) Demographic variables

There are also different measures used for demographic variables, for example, labour force, employment, population and immigration.

(2.1) Labour force (Dedrik et al., 2013; Gruber & Koutroumpis, 2011; Jacobsen, 2003; Koutroumpis, 2009; Roller & Waverman, 2001; Sridhar & Sridhar, 2007; Waverman et al., 2005)

(2.2) Employment as a share of total population (Ding et al., 2008)

(2.3) Urban population as a share of total population (Ding et al. , 2008)

(2.4) Share of the country in the world population (Vu, 2011)

(2.5) Population growth (Datta & Agarwal, 2004; Ding & Haynes, 2006; Ding et al., 2008; Madden & Savage, 1998; Norton, 1992; Zahra et al., 2008)

(2.6) Immigration (Dedrick et al., 2013)

4.2.4.3 Controlling other effects

There are also other important indicators in the literature which cannot be classified as economic or social indicators.

1.) Institutional variables

(1.1) Tax climate (Crandall et al., 2007)

(1.2) Transparency Index (Dimelis & Papaioannou, 2010)

(1.3) The country's Rule of Law Index (Vu, 2011)

2.) Geographical variable

Dummy variable for Baltic States (Madden & Savage, 1998)

3.) Transportation variable

Transportation density as measured by the length of rail, highway and waterway networks per square kilometre (Ding & Haynes, 2006; Ding et al., 2008)

4.2.5 Dependent variables

In order to measure the impact of telecommunication variables on economic development, researchers have to choose the appropriate dependent variable representing economic development. As shown in Table 4-5, two main groups of dependent variables used in the study of the relationship between telecommunications and economic development are the level of economic outputs and the growth rates of outputs.

Table 4-5: List of dependent variables in related studies

Dependent variables	Description	Authors
GDP	Level of output (GDP)	Waverman et al. (2005)
	GDP in million USD	Koutroumpis (2009)
	GDP in million 2000 USD	Gruber & Koutroumpis (2011)
Log of GDP	Log of GDP in billion 1985 USD	Roller & Waverman (2001)
	Log of GDP in billion 1995 USD	Jacobsen (2003)
	Log of real GDP in USD	Sridhar & Sridhar (2007)
GDP per capita	Gross domestic product per head	Hardy (1980)
	GDP per capita PPP adjusted	Dedrick et al. (2013)
GDP per worker	Real GDP per employed person	Atif et al. (2012)
Log of GDP per capita		Czernich et al. (2011)
Growth rate of domestic product	Mean annualised growth rate in real gross domestic product per capita	Norton (1992)
	Growth of real GDP per capita	Madden & Savage (1998)
	Growth of real GDP per capita	Datta & Agarwal (2004)
	Annual growth rate of real GDP per capita	Ding et al. (2008)
	Growth in real GDP per capita	Zahra et al. (2008)
	Growth of GDP per capita	Czernich et al. (2011)
	Average GDP growth rate	Vu (2011)
Growth rate of output per worker		Dimelis & Papaioannou (2010)
TFP growth	Average TFP growth	Lam & Shiu (2010)

4.2.5.1 The level of economic outputs

Economic output is a direct measure of the size of the economy. The level of output could be either measured directly or measured in per capita terms.

1.) Gross domestic product (GDP) is measured directly in a specific currency (Gruber & Koutroumpis, 2011; Koutroumpis, 2009; Waverman et al., 2005). Otherwise, it can appear in a logarithmic form, for example, the logarithm of real GDP (Jacobsen, 2003; Roller & Waverman, 2001; Sridhar and Sridhar, 2007).

2.) The level of output per capita is measured in various forms, for example, GDP per capita (Dedrick et al., 2013; Hardy, 1980), real GDP per employed person (Atif et al., 2012) and the log of real GDP per capita (Czernich et al., 2011).

Additionally, Hardy (1980) also used energy consumption per capita as an indicator of economic development.

4.2.5.2 Growth rates of outputs

Avoiding the impact of the significant difference in the size of economies across countries, growth rates of outputs are used instead of measurement in level terms. There are two categories of growth rates used: output growth and total factor productivity (TFP) growth.

1.) Output growth

Output growth is measured in terms of growth of GDP per capita (Czernich et al., 2011; Datta & Agarwal, 2004; Ding et al., 2008; Madden & Savage, 1998; Norton, 1992; Zahra et al., 2008) and growth of output per worker (Dimelis & Papaioannou, 2010). Alternatively, Vu (2011) measures average GDP growth rate.

2.) TFP growth is measured as an average of TFP growth in Lam and Shiu (2010).

4.2.6 Estimation Methods

The regression analysis used in studying the relationship between telecommunication and growth includes both static and dynamic models. Table 4-6 presents estimation methods used in each study.

4.2.6.1 Static models

For static models, there are two main types of regression used which are cross-section and panel data regressions

1.) Cross-section regression is used by Norton (1992)

2.) Panel data regression

For static panel data regression, there are three main techniques used: OLS, fixed effect and random effect models. These three techniques are combined differently in the literature, for example, Madden and Savage (1998) use the OLS method, Atif et al. (2012) utilise the static fixed effects model, OLS and fixed effect LSDV are employed in Ding et al. (2008), and Dedrick et al. (2013) apply both fixed and random effects models.

4.2.6.2 Dynamic models

For dynamic models, GMM, the dynamic model and IV estimates are the three main technique used.

1.) Generalised method of moments (GMM)

There are several kinds of GMM methods that have been used in recent literature. While Vu (2011) applies Arellano-Bond GMM method for the estimations, Roller and Waverman (2001) use non-linear GMM estimates. Koutroumpis (2009) and Gruber and Koutroumpis (2011) utilise three-stage least squares (3SLS) GMM. System GMM is used in Ding et al. (2008). Waverman et al. (2005) also use the GMM method for the system of equations.

2.) Dynamic model

The dynamic panel data method is employed in Datta and Agarwal (2004) and Lam and Shiu (2010).

3.) Instrumental variable (IV) estimates

The IV estimates are used in three forms which are IV models, two-stage least squares (2SLS) and three stage least squares (3SLS).

(3.1) Instrumental variable models

Single equation IV estimates are used in Koutroumpis (2009), whereas the second stage of the IV model is used in Czernich et al. (2011). Gruber and Koutroumpis (2011) use IV estimates for the system of equations.

(3.2) Two-stage least squares is used in Dedrick et al. (2013).

(3.3) The three-stage least squares system of equations is used in Sridhar and Sridhar (2007)

A few studies also combine different techniques between static and dynamic models or different combinations within static or dynamic models.

Table 4-6: List of estimation methods in related studies

Authors	Estimation methods	Description
Norton (1992)	Cross-section regression	Kormendi & Meguire (1985) framework including telecommunication variables
Madden & Savage (1998)	OLS	
Roller & Waverman (2001)	Non-linear GMM estimates in a simultaneous model	
Jacobsen (2003)	SUR	Seemingly unrelated regression applied to a system
Datta & Agarwal (2004)	Dynamic panel data method	
Waverman et al. (2005)	GMM method	
Sridhar & Sridhar (2007)	3SLS system of equations	
Ding et al. (2008)	System GMM panel data estimator OLS and fixed effect (LSDV) estimation	
Zahra et al. (2008)	Dynamic fixed effect and random effect models	
Koutroumpis (2009)	Single equation IV estimates 3SLS GMM	
Dimelis & Papaioannou (2010)	System GMM panel data estimator	The method proposed by Arellano & Bover (1995) which is an augmented extension of the Arellano & Bond (1991) first difference GMM estimator
Lam & Shiu (2010)	Dynamic panel data model	

Authors	Estimation methods	Description
Czernich et al. (2011)	OLS estimation Second stage of the instrumental variable model	
Gruber & Koutroumpis (2011)	IV estimates 3SLS GMM	
Vu (2011)	Cross-country regression with fixed effects GMM estimators	OLS with country-specific and time-fixed effects Arellano-Bond GMM estimators
Atif et al. (2012)	Static fixed effects model Linear dynamic model	
Dedrick et al. (2013)	Fixed effects and random effects models 2SLS	

4.2.7 Simultaneous equations for telecommunication infrastructure and economic development

The study of the relationship between telecommunication infrastructure and economic growth is similar to that of public infrastructure because it is subject to reverse causality and simultaneity bias. The effects of telecommunication on economic development will be biased when investment in telecommunication infrastructure is not modelled (Roller & Waverman, 2001). Though these studies might claim that the analysis is on the relationship between telecommunication infrastructure and economic growth, in fact, their specifications are based on aggregate output rather than the rate of growth.

A simultaneous model for telecommunication infrastructure and aggregate output is needed to take into account the issue of simultaneity. This was firstly attempted by Roller and Waverman (2001) using a micromodel jointly estimated with a macro production equation. By doing this, Roller and Waverman (2001) argue that telecommunications sector is endogenized into the aggregate economy. The model consisted of four equations, namely aggregate production function, demand for telecommunication infrastructure, supply of telecommunications investment and telecommunication infrastructure production function. Subsequent studies (Gruber & Koutroumpis, 2011; Jacobsen, 2003; Koutroumpis, 2009; Sridhar & Sridhar, 2007; Waverman et al., 2005) have applied the model with different groups of countries and telecom

infrastructures similar to Roller and Waverman (2001). The only key difference appears in Waverman et al. (2005) where the investment equation is simplified from both supply and investment equations. The list of studies is shown in Table 4-7 by chronological order.

Table 4-7: List of studies using simultaneous equations

Authors	Study periods	Countries	Telecom infrastructures
Roller & Waverman (2001)	1970-1990	21 OECD countries	Fixed telephone
Jacobsen (2003)	1990-1999	84 countries	Fixed telephone Mobile phone Personal computer
Waverman et al. (2005)	1996-2003	38 developing countries	Mobile phone
Sridhar & Sridhar (2007)	1990-2001	63 developing countries	Fixed and mobile phones
Koutroumpis (2009)	2002-2007	22 OECD countries	Broadband infrastructure
Gruber & Koutroumpis (2011)	1990-2007	192 countries	Mobile phone

In further analysis, our study focusses on fixed telephone and mobile phone infrastructures in the system of equations. Then, the simultaneous equations are compared only among the studies which investigate the model under these types of telecommunication infrastructure. The aggregate production function, demand for telecom infrastructure, supply of telecom investment and telecom infrastructure production function are compared among different studies accordingly. We may consider variables included in these equations separately.

Firstly, the aggregate production function is the key equation for establishing the link between telecom infrastructure and aggregate output. Previous studies consistently use the level of GDP to represent output. The penetration rate is a proxy for telecommunication infrastructure. Capital and labour are the main inputs. The measurement of capital is usually netted out of telecommunication capital. Waverman et al. (2005) also additionally included external indebtedness and the rule of law as control variables in the aggregate production function. Due to network externalities, some studies also consider critical mass effect at different levels of penetration (Gruber & Koutroumpis, 2011; Jacobsen, 2003; Roller & Waverman, 2001). The list of variables in the aggregate production function of related studies is presented in Table 4-8.

Table 4-8: Aggregate production function in related studies

Authors	Dependent variables	Telecommunication variables	Control variables
Roller & Waverman (2001)	Real GDP	Fixed telephone penetration rate	Real capital stock Total labour force Time trend
Jacobsen (2003)	Real GDP	Fixed telephone penetration rate Personal computer penetration rate Mobile phone penetration rate	Total labour force Time trend
Waverman et al. (2005)	Level of GDP	Mobile phone penetration rate	Capital net of telecom capital Total labour force Rule of law External indebtedness Time trend
Sridhar & Sridhar (2007)	Real GDP	Penetration	Gross fixed capital net telecom Total labour force
Gruber & Koutroumpis (2011)	Real GDP	Mobile phone penetration Fixed-line penetration	Fixed stock of capital Labour

Secondly, the demand for telecommunication is measured by the penetration rate. The waiting list for main lines is also included in Roller and Waverman (2001), Jacobsen (2003) and Sridhar and Sridhar (2007). There is an alternative specification in Jacobsen (2003) which the demand includes the penetration rates of main lines, mobile phones, personal computers and waiting list for main lines. The price of the service of a particular infrastructure is used as a determinant of demand. Its inclusion is useful in measuring price elasticity of demand. In the studies of demand for mobile phone telecommunication, fixed-line services price and fixed-line penetration may also be included. GDP per capita is always included as a control variable; therefore, we can estimate income elasticity of demand for telecommunication services. Table 4-9 presents variables included in the demand equation of related studies.

Table 4-9: Demand for telecommunication infrastructure in related studies

Authors	Dependent variables	Telecommunication variables	Control variables
Roller & Waverman (2001)	Main lines and waiting list per capita	Price of telephone service	Real per capita GDP
Jacobsen (2003)	Main lines and waiting list per capita Telestock and waiting list per capita	Price of telephone service	Real per capita GDP
Waverman et al. (2005)	Mobile telecoms penetration	Mobile service price Fixed-line price	GDP per capita Time trend
Sridhar & Sridhar (2007)	Teledensity and waiting list for main lines	Real price of telecommunication services	Real GDP per capita
Gruber & Koutroumpis (2011)	Mobile phone penetration	Mobile service price Fixed-line penetration	GDP per capita Urbanisation

Thirdly, the supply of telecom investment is measured by investment in telecommunication infrastructure. However, Gruber and Koutroumpis (2011) use mobile phone services revenue to represent supply of telecommunication infrastructure. This is mainly due to poor availability of the data for mobile phone infrastructure investment especially from developing countries. The price of the service and the waiting list for main lines jointly determine the supply of telecom investment. Some other control variables have also been included, for example, GDP per capita and urbanisation are included in Gruber and Koutroumpis (2011). Geographic area and government deficit are included in Roller and Waverman (2001), while Jacobsen (2003) includes only geographic area. The list of variables in the supply function is shown in Table 4-10.

Table 4-10: Supply of telecommunication investment in related studies

Authors	Dependent variables	Telecommunication variables	Control variables
Roller & Waverman (2001)	Investment in telecom infrastructure	Waiting list per capita Price of telephone service	Geographic area Government deficit
Jacobsen (2003)	Investment in telecom infrastructure	Waiting list per capita Price of telephone service	Geographic area
Sridhar & Sridhar (2007)	Real telecommunication investment	Waiting list for main lines per 100 population Revenue per user	
Gruber & Koutroumpis (2011)	Mobile revenue	Mobile service price	Urbanisation GDP per capita

Lastly, telecom infrastructure production is measured as a change in the penetration rate. The main determinant of telecom infrastructure production is telecommunication investment. Alternatively, mobile revenue (Gruber & Koutroumpis, 2011) or the price of telecoms (Waverman et al., 2005) has been incorporated. Geographical area is additionally added as a control variable in Roller and Waverman (2001), Jacobsen (2003) and Waverman et al. (2005). This equation in Waverman et al. (2005) has simplified supply and investment equations from Roller and Waverman (2001). Table 4-11 presents variables included in the telecommunication infrastructure production function.

Table 4-11: Telecommunication infrastructure production function in related studies

Authors	Dependent variables	Telecommunication variables	Control variables
Roller & Waverman (2001)	Change in stock of telecom infrastructure	Investment in telecom infrastructure	Geographic area
Jacobsen (2003)	Change in stock of telecom infrastructure	Investment in telecom infrastructure	Geographic area
Waverman et al. (2005)	Growth rate of mobile phone penetration	Price of telecoms	Geographic area Time trend
Sridhar & Sridhar (2007)	Growth of telecom penetration	Real telecommunication investment	
Gruber & Koutroumpis (2011)	Change in mobile phone penetration	Mobile revenue	

4.2.8 Results from previous studies using simultaneous equations

The results from previous studies discussed in this section focus on the literature using a simultaneous model which is the main method for our further analysis. This is classified into different types of telecommunication infrastructure, namely fixed telephone and mobile-cellular telephone infrastructures and inclusion of both fixed telephone and mobile-cellular telephone infrastructures.

4.2.8.1 Fixed telephone infrastructure

Using evidence from 21 high-income OECD countries between 1970 and 1990, a significantly positive causal link between telecommunication infrastructure and economic development is found by Roller and Waverman (2001). The existence

of non-linearities in telecommunications is also verified, suggesting a critical mass phenomenon (Roller & Waverman, 2001). Similarly, the positive impacts of main line on national output are also found by Sridhar and Sridhar (2007) for a group of 63 developing countries. Since the penetration rate for fixed telephones in those developing countries was low during the period of study, Sridhar and Sridhar (2007) did not investigate the critical mass effect.

4.2.8.2 Mobile phone infrastructure

Using the aggregate production function approach with 38 developing countries, Waverman et al. (2005) find positive impacts of mobile phone penetration on output. This result is also supported by the findings of Sridhar and Sridhar (2007) and Gruber and Koutroumpis (2011). Additionally, Gruber and Koutroumpis (2011) show that the output dividend is smaller for countries with a low mobile phone penetration. In other words, the mobile telecommunication contribution to the aggregate output of countries with high mobile phone penetration is higher than that of countries with low mobile phone penetration.

4.2.8.3 Telecom infrastructure

In Sridhar and Sridhar (2007), an increase in total telecom infrastructure penetration, which includes both mobile phone and main line penetration, enhances national output for the sample of developing countries.

Alternatively, the study of Jacobsen (2003) combines three different types of telecommunication infrastructures namely: main telephone lines, mobile phones and personal computers. It has been found that the development of main telephone lines has the largest output effects which are higher than those of mobile phones. On the contrary, no significant impacts are found for increased personal computers at low penetration rate. However, a significant effect on output exists when the penetration rate passes a certain level, supporting the argument for network extrernalities. Futhermore, there are larger output effects from telecommunication infrastructure development in developing countries than in developed countries.

4.3 Analysis of telecommunication infrastructure and economic development (Study 4)

In this section, this study attempts to assess the impacts of telecommunication infrastructure on economic development by using simultaneous equations. This will be referred to as Study 4. The samples consist of 17 developing and 26 high-income OECD Sample 4 countries from Table 4-1 with data from 1975 to 2012. The types of telecommunication infrastructure of interest are fixed telephone and mobile-cellular telephone. While the set of equations for fixed telephone infrastructure is analysed using the framework proposed by Roller and Waverman (2001), the analysis of mobile telephone infrastructure uses the set of equations that appeared in Gruber and Koutroumpis (2011). The models under both frameworks are explained later on in this section and are followed by the results from estimation.

While Roller and Waverman (2001) found the positive impact of fixed telephone infrastructure on aggregate output in high-income OECD countries between 1970 and 1990, Gruber and Koutroumpis (2011) also found the positive effects of mobile telecommunication on GDP using a worldwide dataset between 1990 and 2007. In this study, we expect to find that the positive impacts of fixed telephone infrastructure on economic development in the earlier years, especially before 1990, decreased in the later stage after 1990, when mobile telephones were already introduced. The effects of mobile telecommunication on economic development in high-income countries could also be different from low-income countries. However, we do not have explicit conjecture as to whether the contribution on output from an increase in mobile phone penetration would be higher or lower in developing countries than that of high-income OECD countries.

We expect that an increase in mobile phone penetration may initially replace the productive use of fixed telephones for businesses. Moreover, the increase in mobile phone penetration could be for consumption as opposed to business use or investment, which does not have directly positive effects on aggregate production. With high fixed telephone penetration, mobile infrastructure might not be highly conducive to increases in aggregate output. On the contrary, mobile infrastructure should generate positive impacts on GDP

when fixed telephone penetration remains low. We attempt to verify these hypotheses later in our study.

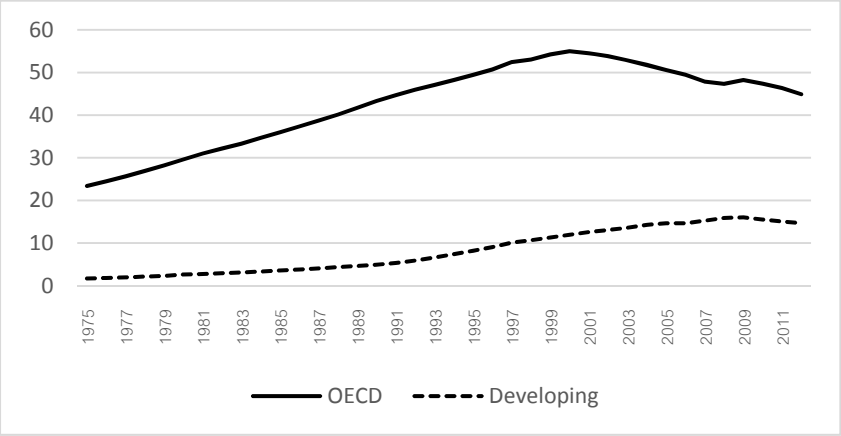


Figure 4-1: Fixed telephone line subscriptions per 100 inhabitants for groups of Sample 4 countries (1975-2012)
Source: ITU

Before analysing the fixed telephone and mobile phone models, we will explain from Figure 4-1 how telecom penetration rates have evolved over time. Fixed telephone subscriptions in high-income OECD Sample 4 countries increased from 23.3% in 1975 and reached its peak at 55.0% in 2000. From then on, the penetration rate decreased gradually to 44.9% in 2012. It is interesting to note that for developing Sample 4 countries, the highest rate was only 16.0%, which was not reached until 2009. The rate declined slightly thereafter to 14.6% in 2012.

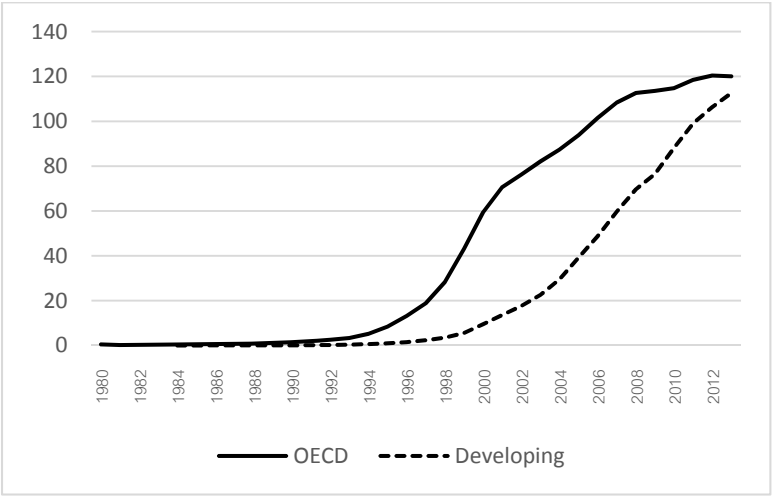


Figure 4-2: Mobile-cellular telephone subscriptions per 100 inhabitants for groups of Sample 4 countries (1980-2012)
Source: ITU

Figure 4-2 shows that mobile-cellular subscriptions have increased greatly over the past few decades. From its introduction in the 1980s, penetration in high-income OECD Sample 4 countries reached a saturation level of 101.5% in 2006. The penetration rate in high-income OECD Sample 4 countries continued to increase gradually from 2006 though it levelled out in 2012 at 120.4%. For developing Sample 4 countries, mobile phone penetration was at 106.3% in 2012 reaching a saturation level in the middle of the year. The difference of the mobile phone penetration rates between both groups of Sample 4 countries in 2012 was much smaller than that difference of fixed telephone penetration.

Mobile telephone penetration in high-income OECD Sample 4 countries surpassed fixed telephone penetration in 2000. For developing Sample 4 countries, the mobile phone penetration rate overtook the fixed telephone rate one year later in 2001. The rise of mobile phone infrastructure was in the same period with the fall of fixed telephone subscriptions, especially for high-income OECD Sample 4 countries between 1990 and 2012.

4.3.1 The models

The variables listed in Table 4-12 are for both the model for fixed telephones and the model for mobile phones. The data for telecommunication variables was collected from the database of the International Telecommunication Union (ITU). The database used is the World Telecommunication/ICT Indicators database 2014 which covers annual data from 1975-2012 of 175 countries around the world. The database includes fixed telephone networks, mobile-cellular telephone subscriptions, quality of service, Internet, traffic, staff, prices, revenue, investment, and statistics on ICT access and use by households and individuals.

Unlike previous studies, our analysis also takes into account stationarity and cointegration of variables in the model. Since the macroeconomic variables included in the model are trended variables, it is likely that these variables might have non-stationarity processes. As a result, this might lead us to the problem of spurious regressions, unless we can find cointegrating relationships between dependent and the set of independent variables.

Firstly, the model for fixed telephones is explained. The second part explains the simultaneous equations for mobile phones. Lastly, we compare both models together.

Table 4-12: List of variables for Study 4

Variables	Description	Sources
GDP	GDP (billion 2005 USD)[8]	World Bank
GDPC	GDP per capita (2005 USD)	World Bank
K	Gross capital formation net of telecom investment (billion 2005 USD)	World Bank /ITU
L	Total employment (in millions)	PWT[9]
TELX	Fixed telephone subscriptions per capita	ITU
MED	Dummy variable = 1 when 0.2 < TELX ≤ 0.4	
HIGH	Dummy variable = 1 when TELX > 0.4	
MOBX	Mobile-cellular telephone subscriptions per capita	ITU
MMED	Dummy variable = 1 when 0.05< MOBX≤ 0.3	
MHIGH	Dummy variable =1 when MOBX >0.3	
t	Time trend	
WLX	Waiting list for fixed telephone lines per capita	ITU
TELP	Revenue from fixed telephone services per subscription	ITU
MOBP	Mobile-cellular post-paid connection charge	ITU
MOBR	Revenue from mobile networks (billion 2005 USD)	ITU
TTI	Annual investment in telecommunication services (billion 2005 USD)	ITU
GA	Land area (sq. km in thousands)	World Bank
URB	Urban population (% of total population)	World Bank
GD	Surplus or deficit (billion 2005 USD)	IMF
USCAN	Dummy variable for USA and Canada from 1983	

4.3.1.1 The simultaneous equations for fixed telephone (Roller and Waverman, 2001)

According to Roller and Waverman (2001), the structural model for fixed telephones includes the following four equations: the aggregate production function, the demand for telecommunication infrastructure, the supply of telecommunication investment and the telecommunication infrastructure production function. We apply this model to developing Sample 4 countries and high-income OECD Sample 4 countries for the period between 1975 and 1990.

- *Aggregate production function*

$$GDP_{it} = f(K_{it},\ L_{it},\ TELX_{it}, t) \quad (1)$$

[8] A billion in this study equals to 10^9.
[9] Referred to PWT9.0 of Feenstra et al. (2015)

For the aggregate production function, the aggregate output (GDP) is related to gross capital formation net of telecommunication investment (K), employment (L), stock of fixed telephone infrastructure (TELX) and time trend (t).

- *Demand for telecommunication infrastructure*

$$TELX_{it} + WLX_{it} = g(GDPC_{it}, TELP_{it}, t) \quad (2)$$

The demand for fixed telephones (the number of fixed telephone lines and waiting list per capita) is a function of GDP per capita (GDPC) and fixed telephone service price. The existence of excess demand at a particular price suggested that the waiting list must be added to the penetration rate. Fixed telephone revenue per subscription (TELP) is used as a proxy of price.

- *Supply of telecommunication investment*

$$TTI_{it} = h(TELP_{it}, GA_{it}, GD_{it}, WLX_{it}, t) \quad (3)$$

Supply is determined by economic, political and geographical variables. Investment in telecommunication (TTI) is related to geographic area (GA), government deficit (GD), waiting list per capita (WLX) and price of fixed telephone service (TELP).

- *Telecommunication infrastructure production function*

$$\Delta TELX_{it} = k(TTI_{it}, GA_{it}, t) \quad (4)$$

For telecommunication infrastructure production, change in stock of fixed telephone infrastructure is determined by telecommunication investment (TTI) and geographical area (GA).

The empirical implementation of the model corresponding to Equation (1) to Equation (4) involves an estimation of the following system of equations, Equation (5) to (8), taking into account non-stationarity and cointegration tests for the variables included in the model.

Baltagi (2005) suggests that the Fisher test for unit roots has the advantage over the IPS (Im, Pesaran and Shin) test in that it does not require a balanced panel. Since we deal with unbalanced panel data, we implement the

Fisher test for unit roots. Based on Fisher-type unit root test (Choi, 2001), the variables included in our model are suggested to be integrated of order 1 and should be treated as non-stationary. There is only an exception for $\Delta log(TELX_{it})$ that is stationary or I(0).

Cointegration means that despite being individually non-stationary, a linear combination of two or more time series can be stationary (Gujarati & Porter, 2009). The cointegrating relationship suggests that there is a long-run, or equilibrium, relationship between those time series. We perform several cointegration tests following Kao (1999), Pedroni (1999, 2004) and Westerlund (2005) for the variables in Equation (1) to Equation (3). The evidence for cointegration is found in all of these equations. As a result, only dependent variables in telecommunication production function (Equation (4)) i.e. TTI_{it} needs to be transformed to avoid spurious regression. All equations in the system also include country-specific fixed effects. We discuss each equation as follows.

- *Aggregate production function*

$$log(GDP_{it}) = a_{0i} + a_1 \log(K_{it}) + a_2 \log(L_{it}) + a_3 \log(TELX_{it}) + a_4 t + \varepsilon_{1it} \quad (5)$$

$$log(GDP_{it}) = a_{0i} + a_1 \log(K_{it}) + a_2 \log(L_{it}) + (a_3 + a_5 MED + a_6 HIGH) * \log(TELX_{it}) + a_4 t + \varepsilon_{1it} \quad (5')$$

The assumption of constant returns to scale (CRTS) is often applied when dealing with macroeconomic problems (Hicks, 1989).[10] This is in agreement with the studies examining the contribution of infrastructure to aggregate output (Canning, 1999; Shahiduzzaman & Alam, 2014). The CRTS property is exhibited in our aggregate production function. Hence, the CRTS assumption implies a parameter restriction of $a_1+a_2+a_3 = 1$ in Equation (5). While the parameters a_1 and a_2 represent the output contribution from capital formation net of telecom investment and labour, the parameter a_3 indicates output contribution from fixed telephone infrastructure.

[10] Hicks (1989) argues that microeceonomics studies pay closed attention to scale economies, while macro-problems often allow to leave this out and apply the constant returns to scale method.

The existence of non-linearities in telecommunications can be tested by using Equation (5'). The dummy variables MED and HIGH represent medium and high fixed telephone penetration rates. If a_5 and a_6 are greater than zero, critical mass theory is supported (Roller & Waverman, 2001). Then, the growth dividend of fixed telephone infrastructure increases with the level of penetration. It must be noted that the meaning of non-linearity is only restricted to the additional output impact from higher level of fixed telephone penetration rates. The relationship between variables in the equation is still linear and the parameters MED and HIGH enter the model with multiplicative relations.

- *Demand for telecommunication infrastructure*

$$log(TELX_{it} + WLX_{it}) = b_0 + b_1\, log(GDPC_{it}) + b_2\, log(TELP_{it}) + b_3 t + \varepsilon_{2it} \quad (6)$$

The parameter b_1 in the demand equation represents income elasticity. If b_1 has positive value, fixed telephone is a normal good. We expect that the demand for fixed telephone increases with income. On the contrary, fixed telephone infrastructure is said to be inferior good when b_1 is negative.

Price elasticity of demand for fixed telephone is determined by the parameter b_2 in Equation (6). The negative correlation between price and demand implies that the higher the price, the lower the demand. The demand is elastic if the value of b_2 is lower than -1 suggesting that there might be close substitutes for fixed telephone infrastructure.

- *Supply of telecommunication investment*

$$log(TTI_{it}) = c_0 + c_1 GD_{it} + c_2\,(1 - USCAN) * (WLX_{it}) + c_3\,(1 - USCAN)\, log(TELP_{it}) + c_4\, USCAN * log(TELP_{it}) + c_5 t + \varepsilon_{3it} \quad (7)$$

Since the telecommunication services in the United States and Canada are provided by private firms, price elasticity of supply for these two countries might be different from other countries. We separately identify price elasticities of supply for the United States and Canada (c_4), and the other countries (c_3) in Equation (7).

The effect of budget balance on telecommunication investment is obscure. As pointed out by Jacobsen (2003), it might be argued that budget deficit constrains telecommunication investment; therefore, the parameter c_1 should be positive. However, large investment in telecommunications can also be a direct cause of budget deficit since it involves other spending programmes.

The impact of an increase in waiting list on telecommunication investment is denoted by parameter c_2. We assume that there is no watiting list if fixed telephone services are provided by private firms.

Since the equation with country fixed effects cannot include a time-invariant variable, the variable for land area (GA) is then omitted from the supply equation.

- *Telecommunication infrastructure production function*

$$\Delta log(TELX_{it}) = d_0 + d_1 \Delta \log(TTI_{it}) + d_2 t + \varepsilon_{4it} \quad (8)$$

Similar to supply equation, the variable for land area is omitted in the telecommunication infrastructure production function. The variable log (TTI_{it}) is transformed to make the series stationary. An increase in the growth rate of investment is expected to have positive impacts on the growth rate of fixed telephone penetration (d_1>0).

4.3.1.2 The simultaneous equations for mobile phones (Gruber & Koutroumpis, 2011)

From Gruber and Koutroumpis (2011), the model for mobile phones includes the following simultaneous equations for the aggregate production function, the demand for mobile phone infrastructure, the supply of mobile phone infrastructure and the mobile phone infrastructure production function. This model is applied to developing Sample 4 countries and high-income OECD Sample 4 countries for the period between 1990 and 2012.

- *Aggregate production function*

$$GDP_{it} = f(K_{it}, L_{it}, MOBX_{it}, TELX_{it}, t) \quad (9)$$

For the aggregate production function, aggregate output is linked to gross capital formation net of telecommunication investment (K), employment (L), stock of mobile phone infrastructure (MOBX) and stock of fixed phone infrastructure (TELX). Since there exists not only mobile phone as a type of telecommunication infrastructure in the period of 1990 to 2012, we need to take into account other types of telecommunication infrastructure. Fixed telephone infrastructure controls for other infrastructure. Furthermore, a time trend (t) is also included. The aggregate production function in the simultaneous equations for fixed telephone is not nested in this equation because the periods of the studies are different. In addition, mobile phone infrastructure was not introduced until the late 1980s. Hence, it is appropriate to focus only on fixed telephone infrastructure in the period between 1975 and 1990.

- *Demand for mobile phone infrastructure*

$$MOBX_{it} = g(GDPC_{it}, URB_{it}, TELX_{it}, MOBP_{it}, t) \quad (10)$$

For the demand equation, mobile phone penetration is a function of the mobile-cellular connection charge (MOBP), urbanisation (URB), GDP per capita (GDPC) and fixed-line penetration (TELX). Fixed-line penetration may capture the effects of network externalities in mobile phone usage.

- *Supply of mobile phone infrastructure*

$$MOBR_{it} = h(GDPC_{it}, URB_{it}, MOBP_{it}, t) \quad (11)$$

For the supply equation, mobile phone revenue is related to the mobile-cellular connection charge (MOBP), urbanisation (URB) and GDP per capita (GDPC). Mobile phone revenue (MOBR) is taken as a proxy of mobile phone infrastructure investment. The reason why mobile phone infrastructure investment is not used, is mainly due to data unavailability.

- *Mobile phone infrastructure production function*

$$\Delta MOBX_{it} = k(MOBR_{it}, t) \quad (12)$$

For mobile phone infrastructure production, the change in mobile phone penetration is a function of mobile phone revenue.

The following equations, Equation (13) to (16), represent the empirical implementation of the model of simultaneous equations in response to Equation (9) to Equation (12).

The Fisher-type unit root test suggests that variables in our model are non-stationary apart from $log(MOBX_{it})$, $log\ (MOBR)_{it}$ and $\Delta log\ (MOBX_{it})$ which are stationary.

While the cointegration test can confirm that there is a long-run relationship between dependent and independent variables in aggregate production function for developing Sample 4 countries, we cannot reject the null hypothesis of no cointegration at 5% significance level for high-income OECD Sample 4 countries which is at the margin (p-value = 0.055). However, the cointegrating relationship between dependent and independent variables in the aggregate production function for high-income OECD Sample 4 countries is confirmed using 10% significance level. We can still argue that there exists a cointegrating relationship between dependent and independient variables in aggregate production function. Hence, transformation of variables in aggregate production function to be stationary is not needed.

For the fact that independent variables in demand, supply and mobile phone infrastructure production equations are non-stationary while the dependent variables are stationary; we need to transform these regressors into first difference. By doing this, we avoid the problem of spurious regressions. However, this would leave the demand and supply equations mixing the variables in both the forms of rate of changes and levels. As a result, $log(MOBX_{it})$ and $log\ (MOBR_{it})$ are also transformed into first difference. The disadvantange of doing this is that we cannot directly interpret the elasticities of demand and supply from our estimates. Similar to the system of equations for fixed telephone, we include country-specific fixed effects in all equations for mobile phone as follows.

- *Aggregate production function*

$$log(GDP_{it}) = a_{0i} + a_1 log\,(K_{it}) + a_2 log\,(L_{it}) + a_3 log\,(MOBX_{it}) + a_4 log\,(TELX_{it}) + a_5 t + \varepsilon_{1it} \quad (13)$$

$$log(GDP_{it}) = a_{0i} + a_1\, log(K_{it}) + a_2\, log(L_{it}) + (a_3 + a_6\, MMED + a_7\, MHIGH) * log\,(MOBX_{it}) + a_4 log\,(TELX_{it}) + a_5 t + \varepsilon_{1it} \quad (13')$$

The constant returns to scale is also applied to the aggregate production function implying that the summation of parameters a_1, a_2, a_3 and a_4 is equal to 1 in Equation (13). Each of these parameters indicates its own contribution to aggregate output.

Non-linearities of mobile phone telecommunication infrastructure may be tested by estimating Equation (13'). *MMED* and *MHIGH* represent medium and high penetration rates of mobile phones. A critical mass effect exists when a_6 and a_7 are greater than zero. When a_6 and a_7 are positive, the output dividend from mobile phone penetration increases with the level of penetration. As discussed earlier, the meaning of non-linearity in this context is restrained to only multiplicative relations between MMED and MHIGH, and MOBX.

- *Demand for mobile phone infrastructure*

$$\Delta\, log(MOBX_{it}) = b_1 \Delta\, log(GDPC_{it}) + b_2\, \Delta log(MOBP_{it}) + b_3\, \Delta log(TELX_{it}) + b_4 \Delta log\,(URB_{it}) + b_5 t + \varepsilon_{2it} \quad (14)$$

Apart from an increase in the growth rate of mobile-cellular connection charge, all variables should exert positive effects on the rate of growth of mobile phone penetration. We expect b_1, b_3 and b_4 to be positive, while b_2 is likely to be negative.

- *Supply of mobile phone infrastructure*

$$\Delta log\,(MOBR)_{it} = c_1 \Delta log\,(GDPC_{it}) + c_2 \Delta log\,(MOBP_{it}) + c_3 \Delta log\,(URB_{it}) + c_4 t + \varepsilon_{3it} \quad (15)$$

The increase in the growth rates of mobile connection charge, urbanisation, and GDP per capita are expected to have positive impacts on the rate of growth of revenue from mobile networks (c_1, c_2 and c_3 >0).

- *Mobile phone infrastructure production function*

$$\Delta log(MOBX_{it}) = d_1 \Delta log(MOBR_{it}) + d_2 t + \varepsilon_{4it} \quad (16)$$

The growth rate of mobile phone penetration rate should be increased as a result of an increase in the rate of growth of mobile phone services revenue (d_1>0).

However, the transformation of variables taken into account stationarity and cointegration makes the dependent variables in both demand and mobile phone infrastructure production function become the same. We need to omit the equation for mobile phone infrastructure production function from our system. It is worth noting that the estimated parameters in the aggregate production function, our main equation of interest, are highly similar with or without mobile phone infrastructure production function.

4.3.1.3 The difference between models for fixed telephone and mobile phone infrastrutures

There are differences between the mobile phone model and the fixed telephone model which need to be compared in each equation starting from the aggregate production function, the demand for telecommunication infrastructure, the supply of telecommunication infrastructure and the telecommunication infrastructure production function.

For the aggregate production function in Equation (9), fixed telephone penetration is also included in the mobile phone equation because fixed telephone infrastructure existed long before mobile phone infrastructure. It can represent other types of telecommunication infrastructure not included in the model. However, the equation for fixed telephones does not include mobile phone infrastructure since the mobile phone infrastructure did not exist until late 1980s.

For the demand equation of mobile phone infrastructure in Equation (10), the dependent variable does not include the waiting list per capita with mobile

phone penetration. This is because excess demand for mobile service does not exist and there is no waiting list. However, urbanisation and fixed telephone penetration are additionally included. While the ratio of urban population can mutually determine the demand for mobile telephone communication, fixed telephone penetration can reflect network externalities from mobile phone usage.

The dependent variable for the supply of mobile phone infrastructure in Equation (11) is mobile phone services revenue. This is different from the fixed telephone equation where investment is used. We use mobile phone revenue as a proxy of mobile phone investment since the available data for investment is very limited. Urbanisation and GDP per capita are also included in the equation. However, geographical area, government surplus and the waiting list for main lines are excluded from mobile phone supply. Since a majority of investment in mobile phone infrastructure is from the private sector, the government budget has minimal effect on the supply of mobile phones and can be dropped from the regression. While geographic area determines the coverage of fixed telephones services, the supply of mobile phone services is highly related to the density of population. Hence urbanisation should be included in supply of mobile phone services rather than geographic area.

Lastly, the independent variable of telecom infrastructure for mobile phone production from Equation (12) is mobile phone revenue. Neither geographic area nor urbanisation is included in this equation. This is consistent with having mobile revenue as a dependent variable in the supply equation. The specification is similar to fixed telephone production function where investment in telecommunications is included as an independent variable. Nonetheless, this equation for mobile phone infrastruture needs to be omitted when we look at the empirical implementation.

In the following analysis, 17 developing Sample 4 countries and 26 high-income OECD Sample 4 countries are examined in two different periods of time: 1975-1990 and 1990-2012. Selected countries have substantial available data from both periods of time. The first period of 1975-1990 is dominated by fixed telephone infrastructure. The second period covers 1990-2012 when the mobile-phone infrastructure has become increasingly important especially after the 1990s. We focus on the analysis of the relationship between mobile phone

infrastructure and economic development while taking into account the existence of fixed telephone infrastructure. The system of equations is estimated via three-stage least squares (3SLS). All dependent variables are treated as endogenous variables. Other variables are treated as exogenous to the system. The equations in our system control for country specific-fixed effects while including a time trend. The alternative specification includes both country-specific and time-specific fixed effects. The assumption of linear relationship between time and dependent variable, where a time trend is included in the equations, might be too restrictive across a sufficiently long period of time. Our discussion will then focus on specifications in which both country and time fixed effects are included.

4.3.2 The regression analysis of telecommunication infrastructure and economic development

In this section, the impacts of fixed telephone and mobile phone infrastructures on economic outputs are analysed controlling for country-specific fixed effects and either time trend or time-specific fixed effects.

4.3.2.1 Fixed telephones

In this analysis of fixed telephones and their impacts on economic development under the framework proposed by Roller and Waverman (2001), the samples used are for the period of 1975 to 1990.

- ***The impacts of fixed telephones on aggregate output between 1975 and 1990***

The analysis of the impacts of the fixed telephones on aggregate output starts with the set of developing Sample 4 countries. The results are shown in Table 4-13.

The estimated aggregate production function shows that increases in capital, labour and fixed telephone penetration enhance aggregate output. The effects of increases in all the inputs on aggregate output are similar in both

cases where we include time trend and time-specific fixed effects. The estimated coefficient for L(L) is 0.57 which is higher than that of combining from both L(K) and L(TELX). It suggests that contribution of human capital to aggregate output is higher than that of physical capital in developing Sample 4 countries.

Table 4-13: Simultaneous equations for impacts of fixed telephones on aggregate output from 1975-1990 for developing Sample 4 countries

Specification/ Equation	**Country fixed with t (1)** b/se	**Two-way fixed (2)** b/se
L(GDP)		
L(K)	0.2299***	0.2312***
	(0.02)	(0.02)
L(L)	0.5670***	0.5676***
	(0.02)	(0.02)
L(TELX)	0.2031***	0.2011***
	(0.03)	(0.02)
T	0.0006	
	(0.00)	
L(TELX+WLX)		
L(GDPC)	0.8579***	0.8619***
	(0.10)	(0.09)
L(TELP)	0.0433	0.0928**
	(0.04)	(0.04)
T	0.0661***	
	(0.00)	
L(TTI)		
GD	-0.0034	-0.0046
	(0.00)	(0.00)
(1-USCAN)*WLX	-9.2988*	-9.5158*
	(5.28)	(5.23)
(1-USCAN)*L(TELP)	0.7335***	0.5798**
	(0.23)	(0.23)
T	0.0314**	
	(0.01)	
Δ L(TELX)		
Δ L(TTI)	-0.0087**	-0.0078*
	(0.00)	(0.00)
T	-0.0010	
	(0.00)	
N	197	197

Notes: (1) Country fixed effects with time trend (2) Country fixed effects and year fixed effects

Standard errors in parentheses below parameters

***, **, * Statistical significance at 1%, 5% and 10% respectively

It must be noted without constant returns to scale restriction, the coeffiecients for L(L) and L(TELX) are much lower. Particularly, the estimated coefficients of L(L) are around 0.21-0.25. We do not examine the critical mass effect of fixed telephone penetration in this sample of countries since the penetration rates of fixed telephone per capita are lower than 0.2.

An increase in GDP per capita has a positive impact on the demand for fixed telephones. The fixed telephone infrastructure can be viewed as a normal good because its demand increases with income. The price elasticity of demand is estimated at 0.04 with time trend or 0.09 with time-specific fixed effects, thus showing that the demand is almost perfectly inelastic. It can be interpreted that fixed telephone infrastructure was a type of communication technology that did not have any close substitutes for the period between 1975 and 1990 in developing Sample 4 countries.

The negative relationship between budget balance and investment in the supply function, suggests that telecom investment could be associated with government deficit. Similar to the explanation given by Roller and Waverman (2001), telecommunication investment involves expenditure in other related projects, leading to a higher budget deficit. However, the coefficients of budget balance are not significant in this case. Excess demand from a waiting list has a negative relationhip with supply. This might be interpreted as being that having a waiting list is a result of supply constraints as suggested by Jacobsen (2003). In contrast, an increase in price generates higher supply. However, supply is inelastic since the coefficient of L(TELP) is lower than 1.

The production function of telecommunication infrastructure is negatively related to growth rate of telecommunication investment. However, the growth effects of this is minimal. A 1% increase in growth rate of investment might reduce growth rate of fixed telephone penetration by 0.008% to 0.009%.

The results for high-income OECD Sample 4 countries appear in Table 4-14. The estimates of the aggregate production function show that increases in capital, labour and fixed telephone penetration enhance aggregate output. The coefficient for each input is similar comparing the equations with time trend (Column (1) and (2)) and the equations with time-specific fixed effects (Column (3) and (4)). The effect on output from the increased penetration in high-income OECD Sample 4 countries (0.30-0.33) is much higher than that of developing

Sample 4 countries (0.20) for the same period of time (1975-1990). It is not a surprising result since the fixed telephone infrastructure is more prevalent in high-income OECD countries than that of developing countries.

Table 4-14: Simultaneous equations for impacts of fixed telephones on aggregate output from 1975-1990 for high-income OECD Sample 4 countries

Specification/ Equation	**Country fixed with t** **(1)** b/se	**Country fixed with t** **(2)** b/se	**Two-way fixed** **(3)** b/se	**Two-way fixed** **(4)** b/se
L(GDP)				
L(K)	0.1507***	0.1515***	0.1401***	0.1424***
	(0.01)	(0.01)	(0.01)	(0.01)
L(L)	0.5336***	0.5493***	0.5313***	0.5459***
	(0.02)	(0.02)	(0.02)	(0.02)
L(TELX)	0.3156***	0.2991***	0.3286***	0.3117***
	(0.01)	(0.01)	(0.01)	(0.01)
MED*LTELX		-0.0164***		-0.0157***
		(0.01)		(0.00)
HIGH*LTELX		-0.0311***		-0.0290***
		(0.01)		(0.01)
T	0.0058***	0.0059***		
	(0.00)	(0.00)		
L(TELX+WLX)				
L(GDPC)	1.2710***	1.2694***	1.3866***	1.3846***
	(0.07)	(0.07)	(0.07)	(0.07)
L(TELP)	-0.2379***	-0.2397***	-0.2169***	-0.2194***
	(0.03)	(0.03)	(0.03)	(0.03)
T	0.0119***	0.0119***		
	(0.00)	(0.00)		
L(TTI)				
GD	0.0011	0.0011	0.0010	0.0010
	(0.00)	(0.00)	(0.00)	(0.00)
(1-USCAN)*WLX	5.5283**	5.5071**	5.1447**	5.1030**
	(2.54)	(2.54)	(2.54)	(2.54)
(1-USCAN)*L(TELP)	0.4488***	0.4505***	0.4770***	0.4793***
	(0.14)	(0.14)	(0.13)	(0.13)
USCAN*L(TELP)	0.4058***	0.4077***	0.4380***	0.4405***
	(0.13)	(0.13)	(0.14)	(0.13)
T	0.0397***	0.0397***		
	(0.00)	(0.00)		
Δ L(TELX)				
Δ L(TTI)	-0.0040	-0.0040	-0.0037	-0.0037
	(0.00)	(0.00)	(0.00)	(0.00)
T	-0.0014***	-0.0014***		
	(0.00)	(0.00)		
N	365	365	365	365

Notes: (1), (2) Country fixed effects with time trend (3), (4) Country fixed effects and year fixed effects

Standard errors in parentheses below parameters

***, **, * Statistical significance at 1%, 5% and 10% respectively

Unlike the findings of Roller and Waverman (2001), marginal output effects do not exist once telecommunication infrastructure has reached universal service. Instead, there could be diminishing returns with medium and high fixed telephone penetration considering critical mass (Column (2) and (4)).

An increase in GDP per capita has a positive impact on demand. Income elasticity of demand in high-income OECD Sample 4 countries is higher than that of developing Sample 4 countries. Demand for fixed telephone in developed countries is more responsive to change in income than that of developing countries. The coefficients of price elasticity of demand is approximately around -0.22 to -0.24 suggesting that demand is inelastic. However, the price elasticity of demand is still higher than that of developing Sample 4 countries. This suggests that in high-income OECD Sample 4 countries, it might be easier to find the substitutable communication technology for fixed telephone.

Similar to developing Sample 4 countries, telecommunication infrastructure investment is not significantly related to government deficits. The positive coefficients could have been interpreted as constraint from investment from budget deficits. However, the results confirm that the effects of budget balance on telecommunication investment is ambiguous. Waiting lists are positively related to investment implying that investment will be increased as a result of excess demand of fixed telephone in high-income OECD Sample 4 countries. Prices are significantly and positively associated with supply. However, supply is inelastic.

The estimated fixed telephone production shows that the growth rate of investment is not significantly related to the rate of change in fixed telephone penetration for high-income OECD Sample 4 countries.

- ***Comparison with the results of Roller and Waverman (2001)***

The results for high-income OECD countries can be compared between our study and Roller and Waverman (2001) as shown in Table 4-15. While the annual data of Roller and Waverman (2001) covers the period from 1970 to 1990, our data is between 1975 and 1990.

Capital, labour and fixed telephone penetration are conducive to growth in both studies. A higher growth dividend is found when telecommunication service has reached the level of high penetration in the study of Roller and Waverman (2001). On the contrary, we find that there could be diminishing returns when service coverage is high. This difference in the results might be due to the inclusion of the other six different countries; Chile, Iceland, Israel, Korea, Luxembourg, and Switzerland, which do not appear in Roller and Waverman (2001). Primarily, the penetration rates of fixed telephone in 1990 are high in Iceland (0.51), Luxembourg (0.48), and Switzerland (0.59). The output contribution of fixed telephones in these countries might be lower than those high-income OECD countries included in Roller and Waverman's (2001) study.

Table 4-15: Comparison between Roller and Waverman's (2001) study and our Study 4 on the relationship between telecommunication infrastructure and aggregate output

Variables/studies	**Roller and Waverman (2001)**	**Our study**
Output equation		
K	Positive significant	Positive significant
L	Positive significant	Positive significant
TELX	Positive significant	Positive significant
MED	Insignificant	Negative significant
HIGH	Positive significant	Negative significant
Year	Negative significant	Positive significant

We argue that the evidence of critical mass effect found by Roller and Waverman (2001) is not robust for high-income OECD countries. The hypothesis of network extenalities for fixed telephone infrastructure still needs further verification. The contribution of increased fixed-telepone penetration to aggregate output of their study is 0.05 which is much lower than our study at 0.32. It suggests that the contribution of fixed telephone on aggregate output is underestimated in Roller and Waverman's (2001) study without controlling for cointegrating relationships between dependent and independent variables in the system of equations.

4.3.2.2 Mobile phones

The impact of mobile phone infrastructure on aggregate output is analysed by using the framework proposed by Gruber and Koutroumpis (2011). The time

period of this study covers 1990 to 2012. We firstly separate the sample according to level of income. Later, the sample is classified according to the level of fixed telephone penetration.

- ***The impacts of mobile telephones on aggregate output between 1990 and 2012 separated by level of income***

We separate our samples into developing Sample 4 countries and high-income OECD Sample 4 countries to account for difference in income level. We will evaluate the results for developing Sample 4 countries from Table 4-16 first.

The estimated aggregate production function shows that increases in capital and labour enhance aggregate output for developing Sample 4 countries. The coefficients of telecom penetration are highly similar comparing the results with time trend and with time-specific fixed effects. A 1% increase in mobile phone penetration could generate a 0.03% to 0.04% increase in aggregate output. The output dividend could even be 0.008% higher comparing a medium penetration rate with low penetration in the equation including time trend (Column (2)). The critical mass effect, however, does not exist with high penetration in both specifications (Column (2) and (4)). The negative contribution of fixed telephone on aggregate output might reflect the prevalence of mobile phone infrastructure that was replacing the usage of fixed telephone as a key communication technology between 1990 and 2012 in developing Sample 4 countries. It is important to note that the estimated parameters for L(L) is much higher than the estimation without constant returns to scale (CRTS) restriction. The coefficients of L(L) in the equations are 0.34 to 0.47 without restriction comparing with 1.02 to 1.07 with this CRTS restriction.

The modification of variables in the model for mobile phone taking into account non-stationarity and cointegration has indicated that the variables in the demand and supply equations need to be transformed into first difference. Hence, it is not possible to directly interpret elasticities of demand and supply in the same way we did with the system of equations for fixed telephone. The telecommunication infrastructure production function is omitted from the model since its dependent variable, after modification, captures the same effect as shown in the demand equation.

Table 4-16: Simultaneous equations for impacts of mobile phones on aggregate output from 1990-2012 for developing Sample 4 countries

Specification/ Equation	Country fixed with t (1) b/se	Country fixed with t (2) b/se	Two-way fixed (3) b/se	Two-way fixed (4) b/se
L(GDP)				
L(K)	0.1099***	0.1078***	0.1015***	0.1044***
	(0.02)	(0.02)	(0.02)	(0.02)
L(L)	1.0255***	1.0175***	1.0703***	1.0643***
	(0.03)	(0.03)	(0.03)	(0.03)
L(MOBX)	0.0327***	0.0369***	0.0340***	0.0350***
	(0.01)	(0.01)	(0.01)	(0.01)
MMED*L(MOBX)		0.0083*		0.0038
		(0.00)		(0.00)
MHIGH*L(MOBX)		0.0172		0.0080
		(0.01)		(0.01)
L(TELX)	-0.1680***	-0.1621***	-0.2058***	-0.2036***
	(0.02)	(0.03)	(0.02)	(0.02)
T	0.0092***	0.0080***		
	(0.00)	(0.00)		
Δ L(MOBX)				
Δ L(GDPC)	1.1328	1.1322	1.7110**	1.7173**
	(0.70)	(0.70)	(0.77)	(0.77)
Δ L(MOBP)	0.0100	0.0097	0.0037	0.0038
	(0.05)	(0.05)	(0.05)	(0.05)
Δ L(TELX)	-0.2907	-0.2972	0.1516	0.1510
	(0.28)	(0.28)	(0.30)	(0.30)
Δ L(URB)	8.8191*	8.8301*	7.0640	7.0345
	(4.85)	(4.85)	(4.45)	(4.45)
T	-0.0384***	-0.0385***		
	(0.01)	(0.01)		
Δ L(MOBR)				
Δ L(GDPC)	0.7036	0.7119	1.0779	1.0972
	(0.74)	(0.74)	(0.81)	(0.81)
Δ L(MOBP)	0.0688	0.0696	0.0669	0.0675
	(0.05)	(0.05)	(0.05)	(0.05)
Δ L(URB)	4.7747	4.5226	5.7669	5.6765
	(5.13)	(5.14)	(4.66)	(4.66)
T	-0.0290***	-0.0290***		
	(0.01)	(0.01)		
N	119	119	119	119

Notes: (1), (2) Country fixed effects with time trend (3), (4) Country fixed effects and year fixed effects
Standard errors in parentheses below parameters
***, **, * Statistical significance at 1%, 5% and 10% respectively

The growth rate of GDP per capita is positively related to growth rate of mobile phone penetration in demand equation as suggested by the results that include time-specific fixed effects (Column(3) and (4)). While changes in price

and fixed telephone penetration do not have significant effect on the rate of change of mobile phone penetration, an increase in the growth rate of urbanisation may have a positive effect on mobile phone penetration growth rate. An increase in urbanisation growth rate of 1% might enhance mobile phone pentration growth rate by 7.0% to 8.8%.

Unlike demand equation, an increase in the growth rate of GDP per capita does not have a significant impact on the mobile phone services revenue growth rate in the supply equation. A change in price is not significantly related to the growth rate of mobile phone revenue earned by firms. Insiginificant relationship between growth rate of mobile phone revenue and urbanisation growth rate is also found.

From Table 4-17 for high-income OECD Sample 4 countries, the aggregate production function is considered first. Aggregate output is enhanced by increases in capital and labour although the coefficients are somewhat different comparing the equations with time trend and the equations with time-specific fixed effects. There is no evidence of mobile phone infrastructure being positively related to aggregate output including when considering critical mass effects. Instead, the increase in mobile phone penetration might slightly decrease aggregate output. It can be noticed that an increase in fixed telephone penetration still has positive impacts on aggregate output. A 1% increase in fixed telephone penetration could enhance aggregate output by 0.14% to 0.16%. It may suggest that while fixed telephone remains a productive input as a mean of communication, an increase in mobile phone penetration in high-income OECD Sample 4 countries does not contribute to production or economic activities.

The growth rate of GDP per capita is positively related with the growth rate of mobile phone penetration in the demand equation only where time trend is included. Additionally, there is an evidence that an increase in the growth rate of mobile connection charge may have negative effect on the growth rate of mobile phone penetration. The rate of changes of fixed telephone penetration, and the growth rate of urbanisation are not significantly related to mobile phone penetration growth rate.

While the growth rate of GDP per capita might be positively related to the rate of growth of mobile phone services revenue, the rate of change of mobile

service price and the urbanisation growth rate are all insignificantly related to the mobile services revenue growth rate in the supply equation.

Table 4-17: Simultaneous equations for impacts of mobile phones on aggregate output from 1990-2012 for high-income OECD Sample 4 countries

Specification/ Equation	Country fixed with t (1) b/se	Country fixed with t (2) b/se	Two-way fixed (3) b/se	Two-way fixed (4) b/se
L(GDP)				
L(K)	0.2026***	0.1964***	0.1673***	0.1665***
	(0.02)	(0.02)	(0.02)	(0.02)
L(L)	0.6502***	0.6599***	0.7307***	0.7311***
	(0.03)	(0.03)	(0.04)	(0.04)
L(MOBX)	-0.0147***	-0.0152**	-0.0366***	-0.0356***
	(0.00)	(0.01)	(0.01)	(0.01)
MMED*L(MOBX)		0.0035		0.0013
		(0.00)		(0.00)
MHIGH*L(MOBX)		-0.0059		0.0017
		(0.01)		(0.01)
L(TELX)	0.1619***	0.1589***	0.1386***	0.1381***
	(0.03)	(0.03)	(0.03)	(0.03)
T	0.0160***	0.0158***		
	(0.00)	(0.00)		
Δ L(MOBX)				
Δ L(GDPC)	1.2521**	1.2491**	0.6608	0.6606
	(0.51)	(0.51)	(0.64)	(0.64)
Δ L(MOBP)	-0.0517*	-0.0514*	-0.0276	-0.0275
	(0.03)	(0.03)	(0.03)	(0.03)
Δ L(TELX)	0.0882	0.0944	-0.3382	-0.3363
	(0.31)	(0.31)	(0.30)	(0.30)
Δ L(URB)	-9.6426	-9.4665	-1.9797	-1.9347
	(7.20)	(7.20)	(6.23)	(6.23)
T	-0.0268***	-0.0268***		
	(0.00)	(0.00)		
Δ L(MOBR)				
Δ L(GDPC)	1.3511**	1.3488**	0.8462	0.8451
	(0.55)	(0.55)	(0.72)	(0.72)
Δ L(MOBP)	0.0004	0.0007	0.0011	0.0012
	(0.03)	(0.03)	(0.03)	(0.03)
Δ L(URB)	-0.1851	0.0378	2.2103	2.2359
	(7.83)	(7.83)	(7.40)	(7.40)
T	-0.0234***	-0.0234***		
	(0.00)	(0.00)		
N	216	216	216	216

Notes: (1), (2) Country fixed effects with time trend (3), (4) Country fixed effects and year fixed effects
Standard errors in parentheses below parameters
***, **, * Statistical significance at 1%, 5% and 10% respectively

- ***The impacts of mobile telephones on aggregate output between 1990 and 2012 separated by level of fixed telephone penetration***

We are also interested whether there is complementarity or substitutability between fixed telephone penetration and mobile phone penetration. If they are complements, an increase in mobile phone penetration would enhance (deteriorate) output when fixed telephone penetration is high (low). If they are substitutes, an increase in mobile phone penetration would enhance (deteriorate) output when fixed telephone penetration is low (high).

In order to identify the relationship between fixed telephone penetration and mobile phone penetration according to the aforementioned aspect, the samples of high-income OECD Sample 4 countries and developing Sample 4 countries are combined together. Then, they are separated evenly into two groups according to the level of fixed telephone penetration. The samples with fixed telephone penetration above 46% are classified as high fixed telephone penetration. Otherwise, the samples with a penetration rate below 46% are classified as low fixed telephone penetration.

For low fixed telephone penetration, an increase in mobile phone penetration has a positive impact on GDP. A 1% increase in mobile phone penetration can improve aggregate output by 0.04% to 0.05%.

For the high fixed telephone penetration, an increase in mobile phone penetration does not enhance GDP level. In contrast, there is some evidence of a deteriorating effect especially when the equations include time-specific fixed effects. A 1% increase in mobile phone penetration could reduce aggregate output by 0.04%. The evidence from our results confirms substitutability between fixed telephones and mobile phones in the same way as the results for the low fixed telephone penetration do.

- ***Comparison with the results of Gruber an Koutroumpis (2011)***

Our results for annual data between 1990 and 2012 are compared with the period from 1990 to 2007 used by Gruber and Koutroumpis (2011) in Table 4-18. While our study focusses on groups of developing countries and high-

income OECD countries within Sample 4, their analysis pooled together low- and high-income countries.

The coefficients on both capital and labour are positive and significant across all groups in the studies (Our Study 4 and Gruber and Koutrompis's (2011) study). The estimated coeffficients of capital and labour for our high-income OECD Sample 4 countries are close to their study. While their study indicates that an increase in mobile phone penetration is conducive to aggregate output, our study has found favourable output impacts only for developing Sample 4 countries. The output contribution from increased mobile phone penetration rate in our study at 0.03% to 0.04% is similar to the estimated from Gruber and Koutroumpis (2011) at 0.03%. However, an increase in mobile phone penetration rate in high-income OECD Sample 4 countries has deteriorating effects on aggregate output.

Table 4-18: Comparison between the study by Gruber and Koutroumpis (2011) and our Study 4 on the relationship between mobile phone infrastructure and aggregate output

Variables/studies	**Gruber and Koutroumpis (2011)**	**Our study***	
	Developed and developing countries	**Developing countries**	**OECD countries**
Output equation			
K	Positively significant	Positively significant	Positively significant
L	Positively significant	Positively significant	Positively significant
MOBX	Positively significant	Positively significant	Negatively significant
MED	Positively significant	Positively significant	Insignificant
HIGH	Positively significant	Insignificant	Insignificant
TELX	Negatively significant	Negatively significant	Positively significant

Note: *Our analysis includes country-specific and time-specific fixed effects in all equations.

Considering critical mass effect, an increase in penetration rate when the level of penetration is in medium level results in increased returns in their study and our developing Sample 4 countries. However, the higher output dividend from a high penetration rate survives only in the results of Gruber and Koutroumpis (2011). This suggests that network externalities may exist only when we consider a wider set of countries.

While an increase in fixed telephone penetration may have negative effect on output in developing Sample 4 countries, the positive contribution is found in high-income OECD Sample 4 countries. This might reflect the

productive usage of this kind of communication technology in high-income countries. This evidence of the difference between developing and high-income countries is not found in the study of Gruber and Koutroumpis (2011), since they do not separate the samples as we did.

4.4 Concluding remarks

The relationship between telecommunication infrastructure and economic development has been assessed by using a simultaneous approach for both fixed telephones and mobile phones using samples from developing Sample 4 countries and high-income OECD Sample 4 countries between 1975 and 2012. Our approach in this chapter has the merit of taking into account stationarity and cointegration among variables in each equation of the system. Furthermore, the restriction of constant returns to scale is also imposed to aggregate production function suggested by Hicks (1989).

For fixed telephone infrastructure, output contribution of high-income OECD Sample 4 countries is higher than that of developing Sample 4 countries in the period of 1975 to 1990. The positive causal link between fixed telephones and aggregate output in high-income OECD Sample 4 countries is consistent with the findings of Roller and Waverman (2001). In our samples, we can only test the critical mass effect for high-income OECD Sample 4 countries. However, the results suggest that there could be diminishing returns when penetration has reached a higher level. This provides evidence against positive network externalities. Since the effects of critical mass do not exist in our case of high-income OECD Sample 4 countries, it could imply that critical mass effect found by Roller and Waverman (2001) is not robust.

For mobile phones, an increase in mobile phone penetration has positive impacts on aggregate output in developing Sample 4 countries. There is evidence of increasing returns with medium mobile phone penetration. For high-income OECD Sample 4 countries, there is weak evidence of mobile phone penetration being negatively related to aggregate output. This contradicts the findings of Gruber and Koutroumpis (2011) in which they found that the impact of mobile telecommunication on growth is smaller for countries with a low level of mobile phone penetration. Though the negative impacts are small, this

finding raises questions about substitutability and complementarity between fixed telephone and mobile phone infrastructures.

To address aforementioned concerns, the samples are separated by level of fixed telephone penetration. With low fixed telephone penetration, an increase in mobile phone penetration has a positive impact on aggregate output. Nonetheless, with high fixed telephone penetration, an increase in mobile phone penetration may impose a deteriorating effect on aggregate output. It implies that fixed telephone and mobile phone infrastructures are subsitutes for one another.

Even though the rise of mobile phone infrastructure has lessened the role of fixed telephones in enhancing economic growth, fixed telephones are still essential in this transition. The investment in mobile phone telecommunication infrastructure in developing countries is still an important driver for economic development since it has been used as a type of communication technology supporting economic activities where fixed telephone service has low coverage. On the contrary, high-income OECD countries would not obtain any further benefit from telecommunication investment unless more productive and efficient ways of utilising mobile telecommunication infrastructure are implemented. This is because fixed telephone usage is already prevalent in high-income OECD countries. Hence, the current usage of mobile phones in high-income OECD countries either replaces fixed telephone or relates to non-productive activities.

Conclusion of the thesis

In these studies, we focus on two different drivers of economic growth: public spending and telecommunication infrastructure. The analysis of the relationship between public expenditure and economic growth was studied in the second chapter, in Study 1, and in the third chapter, in Study 2 and Study 3. The relationship between telecommunication infrastructure and aggregate output was investigated in the fourth chapter, in Study 4.

Results of this study

We begin with the conclusion of the results from these four studies.

Study 1, in the second chapter, is a regression analysis of public expenditure and economic growth, using Bose et al.'s (2007) framework, for groups of countries with different income levels using Sample 1 countries. We also take the problem of endogeneity from taxes and investment, and the possible non-linear relationship between government spending and economic growth into account. The results showed that gross capital formation and initial GDP per capita are significantly related to growth. While an increase in gross capital formation level has a positive effect on growth, the results also indicate that the higher the level of initial GDP per capita is, the lower the rate of growth is. This is consistent with findings of previous studies. However, without controlling for endogeneity, the positive growth impacts of an increase in investment might have been overestimated. There is evidence that transportation and communication spending is significantly related to economic growth in both developing and high-income Sample 1 countries. Other types of functional spending are either negatively or not significantly related to economic growth. Unlike the authors of earlier studies, we cannot find evidence of health spending and education spending being conducive to growth. The non-linear specifications have shown that the relationship between transportation and communication spending and economic growth is concave in both developing and high-income Sample 1 countries. Growth-enhancing effects of increased transportation and communication spending exist up to the level of spending of

8% of GDP in developing Sample 1 countries, but only up to the level of 4% of GDP in high-income Sample 1 countries.

Study 2, in the third chapter, indicates that productive expenditure might only be conducive to economic growth in high-income OECD Sample 2 countries when taking government budget constraint into account. The positive growth effects of an increase in productive expenditure involve with financing by a reduction of non-productive expenditure. The results confirm Kneller et al.'s (1999) findings: that growth impacts of fiscal policy are dependent on the methods used for financing public spending. An increase in distortionary taxes reduces growth across groups of Sample 2 countries with different income levels.

In Study 3, when investigating the relationship between public spending and long-run GDP per capita level while including only the first difference of control variables in short-run effects, an increase in total spending financed by non-distortionary taxes could only enhance GDP per capita in the long run for high-income OECD Sample 3 countries. We have found that excise taxes (which, in this branch of literature, are classified as non-distortionary taxes) should be used for financing public expenditure in high-income OECD Sample 3 countries. With a given level of total spending, an increase in the share of healthcare and general public services spending can improve long-run GDP per capita level in developing Sample 3 countries. In high-income OECD Sample 3 countries, an increase in the share of education spending would have a positive impact on long-run GDP per capita. The estimated speed of adjustment in our study is extremely low, showing the persistent effect of fiscal shock in both developing Sample 3 countries and high-income OECD Sample 3 countries.

In Study 4, in the fourth chapter, we assessed the relationship between telecommunication infrastructure and aggregate output taking stationarity and cointegration tests into account. When considering fixed telephone infrastructure, we found that the output dividend for developing Sample 4 countries is lower than for high-income OECD Sample 4 countries. Unlike Roller and Waverman (2001), we cannot find evidence of a critical mass effect in high-income OECD Sample 4 countries.

Mobile phone penetration is positively related to aggregate output in developing Sample 4 countries. In particular, there is evidence of increasing

returns with medium mobile phone penetration. For high-income OECD Sample 4 countries, there is only weak evidence of mobile phone penetration being negatively related to aggregate output. When there is low fixed telephone penetration, an increase in mobile phone penetration rate would have a positive effect on aggregate output. On the other hand, in the samples which have high fixed telephone penetration, mobile phone penetration is negatively related to output. This implies substitutability between mobile phone and fixed telephone infrastructures.

Policy recommendations

In terms of policy prescriptions, we consider public expenditure and telecommunication infrastructure together.

Firstly, a regression analysis of the relationship between public expenditure and growth has shown that investment is a key driver of growth in all groups of countries. Therefore, governments must create sound environments that support businesses' investment decisions.

Secondly, transportation and communication spending is the only main functional spending that is significantly and positively related to growth. It is important that governments invest sufficiently in public transportation and communication infrastructure. This is particularly important for developing countries, as they have more room to reap the benefits than high-income countries.

Thirdly, an increase in public spending should be financed by non-distortionary taxes, especially excise taxes. Governments should, at least, try to avoid raising distortionary taxes.

Fourthly, some types of public spending should not be curtailed relative to other types of spending (for example, education spending in high-income OECD countries and general public services and health spending in developing countries). Increasing the shares of these types of spending could increase the level of long-run GDP per capita.

Lastly, increase in telecommunication investment can still be a source of economic development in developing countries; however, it might not be beneficial for high-income OECD countries. Policymakers must take care to

select the appropriate set of actions at different stages of telecommunication infrastructure penetration.

Limitations of the studies

The four empirical studies in this thesis have, inevitably, been subject to data issues and econometric difficulties. Most of the data issues that arose involved missing values. For example, our fiscal variables data needed to be combined from several versions of IMF Government Finance Statistics from the UK data service and Gemmell et al. (2011). The method of linear interpolation was also carefully applied in certain cases. When an alternative source of data was not available, we needed to adjust the time frame of our analysis. Hence, the periods of studies used when considering the relationship between public expenditure and economic growth in the second and the third chapters are different due to a lack of control variables, mainly in respect of labour force growth in early years.

In addition, econometric methods cannot always provide ideal solutions. The results presented using the Hausman test and the adjusted R^2 often rely on marginal differences between the best and the second-best methods. The results of the disaggregated analysis between public expenditure and economic growth for groups of countries with different income levels, however, are presented using the two-way fixed effects model. They are then compared with instrumental estimates. Moreover, since unit root tests have low statistical power, we might falsely reject the null hypothesis of the unit root.

Lastly, the analysis of the relationship between telecommunication infrastructure and economic growth could have reverse causality and spurious correlation problems. We attempted to minimise these problems by using a simultaneous model for telecommunication investments and economic growth, and by applying country fixed effects. However, misspecifications may still cause the system estimators to be volatile, which may affect the estimates of all equations. An instrumental variables estimation might provide better estimates if we can find appropriate instruments. While taking stationarity and cointegration of equations into account, we then need to omit an equation for mobile infrastructure production from the model for mobile phones. By doing this, the

interpretation of estimated parameters in the demand and supply equations becomes less meaningful.

Further studies

Lastly, we look at further extension of these studies.

In the second chapter, the permanent growth effects of public expenditure by functions were examined. Each function of public expenditure in Study 1 combines current and capital expenditure. When considering different objectives of public consumption (current expenditure) and public investment (capital expenditure), public expenditure should be separated into current and capital expenditure where data is available. Moreover, further attempts to find an appropriate non-linear term for public spending might improve the accuracy of the estimates.

In Study 2, in the third chapter, government budget constraint is considered together with the growth effects of public expenditure. Our data is restricted to the period from 1991 to 2012, due to unavailability of data on labour. Alternative measures of labour might be used to extend the dataset to earlier years.

When considering the relationship between public spending and long-run level of GDP per capita in Study 3, our samples are restricted to a limited number of developing countries. Inclusion of more developing countries may give a more accurate interpretation of the results for this group of countries.

In the fourth chapter, simultaneous equations of telecommunication infrastructure and aggregate output were analysed. Our Study 4 includes fixed telephone and mobile telephone infrastructures. Consideration of broadband infrastructure and the interaction between these three different types of telecommunications infrastructure may generate systematically different results from previous studies. That could improve the practicality of policy recommendations for current situations.

Where possible, developing countries might be classified into middle-income and low-income countries. This classification would give an additional set of results for groups of countries with the same level of economic development. Moreover, countries in certain geographical areas may have

substantial numbers of common characteristics. Classification of countries according to geographical area could also generate distinct results.

Appendices

Appendix 1: Data of public expenditure and economic growth

Apart from using growth rate of per capita GDP as a dependent variable, the analysis of the relationship between public expenditure and economic growth consists of the other two main sets of independent variables which are the set of fiscal variables and the set of non-fiscal control variables. This section explains how the data is collected and combined. The discussion is on fiscal variables, non-fiscal control variables, missing values and group of countries in our study (Study 1).

1.1 Fiscal variables

Fiscal variables consist of three main categories which are revenue, expenditure by function and expenditure by economic classification according to the IMF's Government Finance Statistics (GFS). In this study, data for revenue and expenditure by function is mainly extracted from the online database of the UK data service. Since there are many levels of the government; the consolidated central government account is chosen for this study. Recent development in government accounting has improved the analytical framework especially for the change from the GFSM 1986 to the GFSM 2001. We will discuss on both the change in analytical framework of GFS and the issues regarding the methods for combining fiscal data. It is important to note that our revenue data bases on GFSM 2001, whereas data for functional public spending bases on both GFSM 1986 and GFSM 2001. Some adjustment to data of public spending by function is required and will be discussed.

1.1.1 The key differences between GFSM 1986 and GFSM 2001

Wickens (2002) has shown the relationship between classification system of GFSM 1986 and GFSM 2001 as follows.

Total revenue and grants in GFSM 1986 are classified to aggregate revenue, except for the sales of fixed capital assets, stocks, and land and intangible assets in GFSM 2001. The sales of fixed capital assets, stocks, and land and intangible assets are classified to the net acquisition of nonfinancial assets (disposals/sales) in GFSM 2001.

The GFSM 1986 aggregate total current expenditure and capital transfers are classified to the GFSM 2001 aggregate expense. The remainder of GFSM 1986 expenditure is classified to the GFSM 2001 net acquisition of nonfinancial assets (acquisitions/purchases).

The aggregate lending minus repayments in the GFSM 1986 is classified to the GFSM 2001 aggregate net acquisition of financial assets.

The GFSM 1986 aggregate financing is separated into two components: the financial assets are classified to the GFSM 2001 aggregate net acquisition of financial assets; the liabilities are classified to the GFSM 2001 aggregate net incurrence of liabilities.

1.1.2 Cash and accrual basis reporting

Transactions of government expenditure and revenue should be reported at the period of time close to payment stage (GFSM 1986). In cash basis, flows are reported when cash is received or disbursed. On the contrary, the flows are recorded at the time economic value is created in accrual basis (GFSM 2001).

Cash basis reporting should be an appropriate representative of governments' activities. Available datasets are also mostly in cash basis. Hence, the data of fiscal variables in this study is mainly from cash basis reporting. If the data from accrual basis is available where cash basis is not, the data from accrual basis would then be used. There are two ways of combining these two different sets of data. First, with some overlapping years between two strings of data, the existing cash basis data is combined with accrual basis data by using the growth rate of accrual ones. If there is no overlapping data, accrual basis data would be added to the existing pool of data from cash basis.

1.1.3 Budgetary central and consolidated central government

In the case of developing countries, some countries report both at the level of budgetary central and consolidated central government. In such a case, two sets of data are combined by using the growth rate from the level of budgetary central government. Where consolidated central government data is not available, budgetary central government data would be simply added into the set of consolidated central government data. Data from recent years is also alternatively reported at the level of general government.

1.1.4 Classification of outlays by functions of government

The main differences between GFSM 1986 and GFSM 2001 classification for government outlays as pointed out by Wickens (2002) are as follows.

Firstly, a category of expenditure which is not classified by major group in GFSM 1986 is classified as a part of general public services category in GFSM 2001. We have found that public debt transactions and transfers of a general character between different levels of government are additionally included into GFSM 2001.

Secondly, a new category of environment protection is added to GFSM 2001. Some parts of environmental expenditure is included under housing and community amenity affairs and services spending in GFSM 1986.

Thirdly, transportation and communication spending in GFSM 1986 cannot be separated into transport and communication categories.

Fourthly, housing and community affairs spending in GFSM 2001 excludes the subcategory of sanity affairs and services including pollution abatement and control from GFSM 1986. This is re-classified to environmental protection.

Lastly, the GFSM 2001 classifies outlays on research and development as a separate group. In most GFSM 1986 divisions, expenditures on research and development are not identified separately.

The relevant changes that need to take into account into our data compilation relate to transportation and communication, and general public services spending. We combine transportation spending and communication

spending together as a category of spending. For general public services, we exclude public debt transactions and transfers from the series of our data.

1.1.5 Combining data with alternative sources for high-income OECD countries

The data from the other sources are also combined with the data from UK data service to fill up missing values of high-income OECD countries. There are two additional sources. First, the data from Gemmell et al. (2011) consists of data from 17 high-income OECD countries between 1972 and 2004. In their study, government revenue is reported as a share of GDP while public expenditure by function is reported as percentage of total spending. We combine our dataset with this set of data by using the ratios given in order to increase the number of observations for analysis. Secondly, some of the data in the most recent years is also combined from OECD statistics.

1.2 Non-fiscal control variables

The set of control variables are mainly extracted from the World Bank's World Development Indicators' (WDI) 2015 online database. Only the data of political instability index comes from the Center for Systemic Peace's Coups d'Etat 1946-2014 data. There are two control variables (school enrolment and political instability index) which are calculated by the author.

1.2.1 School enrolment (PST)

School enrolment is calculated by using a linear combination of the gross school enrolment at primary (GEP), secondary (GES) and tertiary (GET) level. The higher weight is given to the higher education level from 1 to 3 respectively following the method used in Bose et al. (2007).

1.2.2 Political instability index (PINST)

Political instability index is calculated from the average number of successful coups (number of successful coups d'état that occurred in the year of record) and assassinations of executive (Indicator of the assassination of the ruling executive during the year of record). These two variables appear in the data set of Coups d'Etat 1946-2014 from Center for Systematic Peace. The method of calculation is mainly based on Bose et al. (2007).

1.3 Missing values

Combining different sets of data across countries is subject to significant loss of information especially at disaggregated level. Some of the gaps between two years are filled by using linear trend or interpolation. This is done by careful consideration regarding consistency with the variables at aggregate level for example, total revenue, total expenditure, productive expenditure, non-productive expenditure and other expenditure - the summation of productive and non-productive expenditure must not exceed total spending.

1.4 Groups of countries (Study 1)

The countries are separated mainly into developing countries and high-income countries. The developing countries are the countries with either low income or middle income according to the definition of the World Bank. The set of OECD countries is a subset of high-income countries.

The countries with minimal availability of revenue and expenditure by functions data are excluded from this analysis. The selected 75 countries (37 developing countries, 38 high-income countries, 31 high-income OECD countries) in Table 2-1 (as shown in Chapter 2) are used in the analysis of Chapter 2. These groups of countries are referred to as Sample 1.

Appendix 2: Growth regressions with functional spending of Sample 1 countries (1972-2012)

The growth regressions with total, and transportation and communication spending are presented in Chapter 2. In this section, fiscal-growth relationship in the endogenous growth model of developing and high-income Sample 1 countries are presented for general public services, defence, health, education and social welfare spending.

2.1 Developing Sample 1 countries

Growth regressions with functional spending of developing Sample 1 countries are illustrated in Table A1 to Table A5. The relationship between general public services, defence and health spending and per capita GDP growth of developing Sample 1 countries are insignificant. The linear specification has shown that an increase in education and social welfare spending may produce growth-diminisihing effect. The non-linear specification reveals that increased education spending can promote growth when the level of education spending is below 4% of GDP.

2.2 High-income Sample 1 countries

The estimates of high-income Sample 1 countries from Table A6 to Table A10 show that defence and health spending are not significantly related to economic growth. An increase in general public services, education and social welfare spending can bring about adverse impacts on growth. The non-linear specification has shown that the square term of education spending is positive. An increase in education spending can enhance growth at its high level of spending. This may represent the primary role of the government in certain countries in providing educational service, while the other countries might provide this service privately.

Table A1: Growth regressions with general public services spending of developing Sample 1 countries (1972-2012)

Estimation method	OLS	2SLS	2SLS	2SLS	2SLS	2SLS
Dependent variable	GR	GR	GR	GR	GR	GR
Endogenous variable		tax_gdp K	tax_gdp K	tax_gdp K	tax_gdp K	tax_gdp K
	(1)	**(2)**	**(3)**	**(4)**	**(5)**	**(6)**
Regressor	**b/se**	**b/se**	**b/se**	**b/se**	**b/se**	**b/se**
Initial GDP per capita	-7.4984***	-6.5937***	-6.2010***	-7.2529***	-7.0119***	-6.9841***
	(1.08)	*(1.13)*	*(1.26)*	*(1.16)*	*(1.29)*	*(1.29)*
Initial school enrolment	-0.0325	-0.0507	-0.0447	-0.0430	-0.0414	-0.0229
	(0.05)	*(0.05)*	*(0.05)*	*(0.05)*	*(0.05)*	*(0.05)*
Initial life expectancy	-1.9193	5.8027	10.2084**	10.2834**	14.0440***	14.1979***
	(4.60)	*(4.97)*	*(5.02)*	*(4.99)*	*(5.04)*	*(5.02)*
Gross capital formation (% of GDP)	0.2250***	0.0895**	0.0754**	0.0491	0.0424	0.0437
	(0.03)	*(0.04)*	*(0.04)*	*(0.04)*	*(0.04)*	*(0.04)*
Taxes (% of GDP)	-0.1576***	-0.1744***	-0.1656**	-0.2253***	-0.3264***	-0.2981***
	(0.05)	*(0.06)*	*(0.07)*	*(0.08)*	*(0.10)*	*(0.11)*
Political instability	-3.1600	-3.2656	-3.3409*	-3.2560*	-3.3615*	-3.3902*
	(2.00)	*(1.99)*	*(1.97)*	*(1.96)*	*(1.94)*	*(1.94)*
M2 (% of GDP)			-0.0500***		-0.0316**	-0.0345**
			(0.02)		*(0.02)*	*(0.02)*
Trade (% of GDP)			0.0445***		0.0434***	0.0404***
			(0.01)		*(0.01)*	*(0.01)*
Budget surplus (% of GDP)				0.3277***	0.3912***	0.4116***
				(0.06)	*(0.07)*	*(0.07)*
General public services spending (% of GDP)	-0.1040	-0.1461*	-0.1491*	0.0576	0.0658	-0.0306
	(0.08)	*(0.08)*	*(0.08)*	*(0.09)*	*(0.09)*	*(0.23)*
Other spending (% of GDP)				0.0895*	0.1424**	-0.0474
				(0.05)	*(0.06)*	*(0.06)*
Square term of general public services spending (% of GDP)						0.0062
						(0.02)
Square term of other spending (% of GDP)						0.0030**
						(0.00)
Number of observations	877	850	841	842	833	833

Notes: Standard errors in parentheses below parameters

***, **, * Statistical significance at 1%, 5% and 10% respectively

Table A2: Growth regressions with defence spending of developing Sample 1 countries (1972-2012)

Estimation method	OLS	2SLS	2SLS	2SLS	2SLS	2SLS
Dependent variable	GR	GR	GR	GR	GR	GR
Endogenous variable		tax_gdp K	tax_gdp K	tax_gdp K	tax_gdp K	tax_gdp K
	(1)	**(2)**	**(3)**	**(4)**	**(5)**	**(6)**
Regressor	**b/se**	**b/se**	**b/se**	**b/se**	**b/se**	**b/se**
Initial GDP per capita	-7.0299***	-6.0890***	-5.5892***	-6.6283***	-6.2525***	-5.9496***
	(1.08)	*(1.14)*	*(1.29)*	*(1.16)*	*(1.34)*	*(1.33)*
Initial school enrolment	-0.0187	-0.0286	-0.0272	-0.0290	-0.0278	-0.0265
	(0.05)	*(0.05)*	*(0.05)*	*(0.05)*	*(0.05)*	*(0.05)*
Initial life expectancy	-7.1914	3.4188	8.0947	9.1693*	12.7863**	10.9804**
	(4.51)	*(4.95)*	*(4.97)*	*(5.11)*	*(5.11)*	*(5.21)*
Gross capital formation (% of GDP)	0.2575***	0.0975**	0.0808**	0.0572	0.0467	0.0592
	(0.03)	*(0.04)*	*(0.04)*	*(0.04)*	*(0.04)*	*(0.04)*
Taxes (% of GDP)	-0.1234**	-0.1063	-0.0616	-0.1477*	-0.2040*	-0.1149
	(0.05)	*(0.07)*	*(0.08)*	*(0.09)*	*(0.12)*	*(0.13)*
Political instability	-2.9319	-3.1098	-3.2059*	-3.0701	-3.2521*	-3.1181*
	(1.92)	*(1.92)*	*(1.89)*	*(1.91)*	*(1.89)*	*(1.87)*
M2 (% of GDP)			-0.0586***		-0.0424***	-0.0500***
			(0.02)		*(0.02)*	*(0.02)*
Trade (% of GDP)			0.0498***		0.0487***	0.0455***
			(0.01)		*(0.01)*	*(0.01)*
Budget surplus (% of GDP)				0.2664***	0.2993***	0.3040***
				(0.06)	*(0.08)*	*(0.08)*
Defence spending (% of GDP)	0.0028	0.0033	-0.0217	0.1094	0.0775	-0.2304
	(0.12)	*(0.12)*	*(0.12)*	*(0.12)*	*(0.12)*	*(0.33)*
Other spending (% of GDP)				0.0515	0.0971	-0.1407
				(0.05)	*(0.07)*	*(0.07)*
Square term of defence spending (% of GDP)						0.0224
						(0.02)
Square term of other spending (% of GDP)						0.0035***
						(0.00)
Number of observations	865	836	827	829	820	820

Notes: Standard errors in parentheses below parameters

***, **, * Statistical significance at 1%, 5% and 10% respectively

Table A3: Growth regressions with education spending of developing Sample 1 countries (1972-2012)

Estimation method	OLS	2SLS	2SLS	2SLS	2SLS	2SLS
Dependent variable	GR	GR	GR	GR	GR	GR
Endogenous variable		tax_gdp K	tax_gdp K	tax_gdp K	tax_gdp K	tax_gdp K
	(1)	**(2)**	**(3)**	**(4)**	**(5)**	**(6)**
Regressor	**b/se**	**b/se**	**b/se**	**b/se**	**b/se**	**b/se**
Initial GDP per capita	-6.9974***	-6.4004***	-6.0992***	-6.9048***	-6.7969***	-6.8248***
	(1.05)	*(1.10)*	*(1.23)*	*(1.13)*	*(1.26)*	*(1.24)*
Initial school enrolment	0.0237	0.0081	0.0048	-0.0021	-0.0049	-0.0121
	(0.05)	*(0.05)*	*(0.05)*	*(0.05)*	*(0.05)*	*(0.05)*
Initial life expectancy	-8.2336*	-0.3805	4.4742	5.8958	9.8582*	5.6326
	(4.47)	*(4.86)*	*(4.96)*	*(4.96)*	*(5.06)*	*(5.24)*
Gross capital formation (% of GDP)	0.2620***	0.1240***	0.1033***	0.0795**	0.0663*	0.0963**
	(0.03)	*(0.04)*	*(0.04)*	*(0.04)*	*(0.04)*	*(0.04)*
Taxes (% of GDP)	-0.0254	-0.0548	-0.0554	-0.1240	-0.2273**	-0.2139**
	(0.05)	*(0.07)*	*(0.07)*	*(0.09)*	*(0.11)*	*(0.11)*
Political instability	-3.2981*	-3.3594*	-3.4017*	-3.3538*	-3.4133*	-3.3389*
	(1.95)	*(1.94)*	*(1.93)*	*(1.92)*	*(1.91)*	*(1.88)*
M2 (% of GDP)			-0.0481***		-0.0305*	-0.0417***
			(0.02)		*(0.02)*	*(0.02)*
Trade (% of GDP)			0.0390***		0.0395***	0.0409***
			(0.01)		*(0.01)*	*(0.01)*
Budget surplus (% of GDP)				0.3091***	0.3692***	0.4079***
				(0.06)	*(0.07)*	*(0.07)*
Education spending (% of GDP)	-1.0842***	-0.8455***	-0.6885***	-0.6538***	-0.4340*	0.7325*
	(0.19)	*(0.21)*	*(0.21)*	*(0.22)*	*(0.23)*	*(0.44)*
Other spending (% of GDP)				0.0840*	0.1285**	0.0287
				(0.05)	*(0.06)*	*(0.06)*
Square term of education spending (% of GDP)						-0.0966***
						(0.03)
Square term of other spending (% of GDP)						0.0013
						(0.00)
Number of observations	888	858	849	851	842	842

Notes: Standard errors in parentheses below parameters

***, **, * Statistical significance at 1%, 5% and 10% respectively

Table A4: Growth regressions with healthcare spending of developing Sample 1 countries (1972-2012)

Estimation method	OLS	2SLS	2SLS	2SLS	2SLS	2SLS
Dependent variable	GR	GR	GR	GR	GR	GR
Endogenous variable		tax_gdp K	tax_gdp K	tax_gdp K	tax_gdp K	tax_gdp K
	(1)	**(2)**	**(3)**	**(4)**	**(5)**	**(6)**
Regressor	**b/se**	**b/se**	**b/se**	**b/se**	**b/se**	**b/se**
Initial GDP per capita	-7.6059***	-6.6595***	-6.2702***	-7.1528***	-7.0168***	-6.7076***
	(1.08)	*(1.13)*	*(1.25)*	*(1.16)*	*(1.27)*	*(1.27)*
Initial school enrolment	-0.0216	-0.0330	-0.0287	-0.0388	-0.0328	-0.0367
	(0.05)	*(0.05)*	*(0.05)*	*(0.05)*	*(0.05)*	*(0.05)*
Initial life expectancy	-1.7608	4.9917	9.0692*	10.8935**	14.3095***	14.3229***
	(4.53)	*(4.94)*	*(4.99)*	*(4.97)*	*(5.01)*	*(4.97)*
Gross capital formation (% of GDP)	0.2297***	0.0949**	0.0789**	0.0513	0.0461	0.0545
	(0.03)	*(0.04)*	*(0.04)*	*(0.04)*	*(0.04)*	*(0.04)*
Taxes (% of GDP)	-0.1196**	-0.1368**	-0.1292*	-0.1998**	-0.2912***	-0.2856***
	(0.05)	*(0.07)*	*(0.07)*	*(0.08)*	*(0.10)*	*(0.10)*
Political instability	-3.0662	-3.1523	-3.2433*	-3.1779	-3.2943*	-3.1886*
	(1.99)	*(1.98)*	*(1.96)*	*(1.95)*	*(1.93)*	*(1.92)*
M2 (% of GDP)			-0.0510***		-0.0314**	-0.0335**
			(0.02)		*(0.02)*	*(0.02)*
Trade (% of GDP)			0.0435***		0.0435***	0.0370***
			(0.01)		*(0.01)*	*(0.01)*
Budget surplus (% of GDP)				0.3276***	0.3932***	0.4310***
				(0.06)	*(0.07)*	*(0.07)*
Health spending (% of GDP)	-0.3441	-0.2291	-0.1561	-0.0733	-0.0765	1.2339*
	(0.22)	*(0.23)*	*(0.23)*	*(0.24)*	*(0.23)*	*(0.72)*
Other spending (% of GDP)				0.0868*	0.1379**	-0.0456
				(0.05)	*(0.06)*	*(0.06)*
Square term of health spending (% of GDP)						-0.1997*
						(0.11)
Square term of other spending (% of GDP)						0.0025**
						(0.00)
Number of observations	883	854	845	847	838	838

Notes: Standard errors in parentheses below parameters

***, **, * Statistical significance at 1%, 5% and 10% respectively

Table A5: Growth regressions with social welfare spending of developing Sample 1 countries (1972-2012)

Estimation method	OLS	2SLS	2SLS	2SLS	2SLS	2SLS
Dependent variable	GR	GR	GR	GR	GR	GR
Endogenous variable		tax_gdp K	tax_gdp K	tax_gdp K	tax_gdp K	tax_gdp K
	(1)	**(2)**	**(3)**	**(4)**	**(5)**	**(6)**
Regressor	**b/se**	**b/se**	**b/se**	**b/se**	**b/se**	**b/se**
Initial GDP per capita	-8.0379***	-7.0533***	-6.7972***	-7.6455***	-7.4726***	-7.3176***
	(1.14)	*(1.19)*	*(1.32)*	*(1.22)*	*(1.34)*	*(1.36)*
Initial school enrolment	-0.0011	-0.0165	-0.0133	-0.0263	-0.0194	-0.0129
	(0.05)	*(0.05)*	*(0.05)*	*(0.05)*	*(0.05)*	*(0.05)*
Initial life expectancy	-1.1245	5.7779	10.0005**	11.7502**	14.8318***	14.3363***
	(4.56)	*(4.97)*	*(5.03)*	*(4.99)*	*(5.05)*	*(5.06)*
Gross capital formation (% of GDP)	0.2211***	0.0874**	0.0724*	0.0435	0.0382	0.0349
	(0.03)	*(0.04)*	*(0.04)*	*(0.04)*	*(0.04)*	*(0.04)*
Taxes (% of GDP)	-0.1154**	-0.1332**	-0.1136	-0.2028**	-0.2906***	-0.2671**
	(0.05)	*(0.07)*	*(0.07)*	*(0.08)*	*(0.10)*	*(0.10)*
Political instability	-3.1242	-3.1953	-3.3151*	-3.2690*	-3.3985*	-3.4415*
	(2.01)	*(2.00)*	*(1.98)*	*(1.97)*	*(1.95)*	*(1.95)*
M2 (% of GDP)			-0.0522***		-0.0336**	-0.0357**
			(0.02)		*(0.02)*	*(0.02)*
Trade (% of GDP)			0.0438***		0.0430***	0.0403***
			(0.01)		*(0.01)*	*(0.01)*
Budget surplus (% of GDP)				0.3365***	0.3974***	0.4210***
				(0.06)	*(0.07)*	*(0.07)*
Social welfare spending (% of GDP)	-0.2603**	-0.2338**	-0.2033*	-0.1189	-0.0540	-0.1444
	(0.11)	*(0.12)*	*(0.12)*	*(0.12)*	*(0.12)*	*(0.25)*
Other spending (% of GDP)				0.1045**	0.1507**	0.0284
				(0.05)	*(0.06)*	*(0.06)*
Square term of social welfare spending (% of GDP)						0.0070
						(0.02)
Square term of other spending (% of GDP)						0.0018*
						(0.00)
Number of observations	865	836	827	829	820	820

Notes: Standard errors in parentheses below parameters

***, **, * Statistical significance at 1%, 5% and 10% respectively

Table A6: Growth regressions with general public services spending of high-income Sample 1 countries (1972-2012)

Estimation method	OLS	2SLS	2SLS	2SLS	2SLS	2SLS
Dependent variable	GR	GR	GR	GR	GR	GR
Endogenous variable		tax_gdp K	tax_gdp K	tax_gdp K	tax_gdp K	tax_gdp K
	(1)	**(2)**	**(3)**	**(4)**	**(5)**	**(6)**
Regressor	**b/se**	**b/se**	**b/se**	**b/se**	**b/se**	**b/se**
Initial GDP per capita	-8.0013***	-5.9576***	-5.7212***	-5.3546***	-5.3431***	-5.2597***
	(0.81)	*(0.93)*	*(1.02)*	*(0.97)*	*(1.07)*	*(1.10)*
Initial school enrolment	0.0455***	0.0089	0.0045	0.0223	0.0120	0.0215
	(0.02)	*(0.02)*	*(0.02)*	*(0.02)*	*(0.02)*	*(0.02)*
Initial life expectancy	12.9498*	27.5329***	30.2415***	24.4433***	26.4417***	25.3618***
	(7.58)	*(8.60)*	*(9.16)*	*(8.51)*	*(9.05)*	*(9.18)*
Gross capital formation (% of GDP)	0.3988***	0.0496	0.0435	0.0088	0.0200	0.0048
	(0.03)	*(0.04)*	*(0.05)*	*(0.05)*	*(0.05)*	*(0.05)*
Taxes (% of GDP)	-0.0664*	-0.1036**	-0.0715	0.0101	-0.0862	-0.1229
	(0.04)	*(0.05)*	*(0.06)*	*(0.09)*	*(0.11)*	*(0.11)*
Political instability	2.0231	2.2330	2.6227	2.5377	3.1055	3.5557
	(2.38)	*(2.53)*	*(2.57)*	*(2.50)*	*(2.53)*	*(2.55)*
M2 (% of GDP)			-0.0148***		-0.0114**	-0.0130***
			(0.00)		*(0.00)*	*(0.00)*
Trade (% of GDP)			0.0283***		0.0278***	0.0216**
			(0.01)		*(0.01)*	*(0.01)*
Budget surplus (% of GDP)				0.0225	0.1113	0.1327*
				(0.06)	*(0.07)*	*(0.07)*
General public services spending (% of GDP)	-0.1495***	-0.1350**	-0.1714**	-0.1791***	-0.1311*	-0.1014
	(0.05)	*(0.05)*	*(0.07)*	*(0.06)*	*(0.08)*	*(0.21)*
Other spending (% of GDP)				-0.1300**	-0.0457	-0.2914***
				(0.05)	*(0.06)*	*(0.06)*
Square term of general public services spending (% of GDP)						-0.0063
						(0.02)
Square term of other spending (% of GDP)						0.0034***
						(0.00)
Number of observations	1088	1071	896	1062	887	887

Notes: Standard errors in parentheses below parameters

***, **, * Statistical significance at 1%, 5% and 10% respectively

Table A7: Growth regressions with defence spending of high-income Sample 1 countries (1972-2012)

Estimation method	OLS	2SLS	2SLS	2SLS	2SLS	2SLS
Dependent variable	GR	GR	GR	GR	GR	GR
Endogenous variable		tax_gdp K	tax_gdp K	tax_gdp K	tax_gdp K	tax_gdp K
	(1)	**(2)**	**(3)**	**(4)**	**(5)**	**(6)**
Regressor	**b/se**	**b/se**	**b/se**	**b/se**	**b/se**	**b/se**
Initial GDP per capita	-7.8929***	-5.7940***	-5.6477***	-5.1483***	-5.0326***	-4.8794***
	(0.81)	*(0.92)*	*(1.01)*	*(0.93)*	*(1.05)*	*(1.07)*
Initial school enrolment	0.0419**	0.0024	-0.0036	0.0174	0.0058	0.0110
	(0.02)	*(0.02)*	*(0.02)*	*(0.02)*	*(0.02)*	*(0.02)*
Initial life expectancy	12.5183	27.6030***	30.1135***	25.8293***	27.6230***	26.0941***
	(7.62)	*(8.63)*	*(9.19)*	*(8.49)*	*(9.07)*	*(9.22)*
Gross capital formation (% of GDP)	0.3990***	0.0506	0.0535	-0.0021	0.0111	0.0005
	(0.03)	*(0.04)*	*(0.05)*	*(0.05)*	*(0.05)*	*(0.05)*
Taxes (% of GDP)	-0.0899**	-0.1569**	-0.1344*	-0.0557	-0.1438	-0.1632
	(0.04)	*(0.06)*	*(0.07)*	*(0.09)*	*(0.11)*	*(0.11)*
Political instability	1.8649	2.2449	2.6679	3.1413	3.4652	3.6832
	(2.40)	*(2.55)*	*(2.59)*	*(2.50)*	*(2.55)*	*(2.56)*
M2 (% of GDP)			-0.0159***		-0.0131***	-0.0136***
			(0.00)		*(0.00)*	*(0.00)*
Trade (% of GDP)			0.0317***		0.0226**	0.0214**
			(0.01)		*(0.01)*	*(0.01)*
Budget surplus (% of GDP)				-0.0016	0.0909	0.1105
				(0.06)	*(0.07)*	*(0.07)*
Defence spending (% of GDP)	-0.0606	0.0532	0.0139	0.1818*	0.1682	-0.0557
	(0.07)	*(0.10)*	*(0.11)*	*(0.10)*	*(0.11)*	*(0.26)*
Other spending (% of GDP)				-0.1893***	-0.0994	-0.2160*
				(0.05)	*(0.06)*	*(0.06)*
Square term of defence spending (% of GDP)						0.0066
						(0.01)
Square term of other spending (% of GDP)						0.0018
						(0.00)
Number of observations	1091	1073	898	1064	889	889

Notes: Standard errors in parentheses below parameters

***, **, * Statistical significance at 1%, 5% and 10% respectively

Table A8: Growth regressions with education spending of high-income Sample 1 countries (1972-2012)

Estimation method	OLS	2SLS	2SLS	2SLS	2SLS	2SLS
Dependent variable	GR	GR	GR	GR	GR	GR
Endogenous variable		tax_gdp K	tax_gdp K	tax_gdp K	tax_gdp K	tax_gdp K
	(1)	**(2)**	**(3)**	**(4)**	**(5)**	**(6)**
Regressor	**b/se**	**b/se**	**b/se**	**b/se**	**b/se**	**b/se**
Initial GDP per capita	-8.1251***	-5.7662***	-5.5448***	-5.4960***	-5.4312***	-4.6895***
	(0.81)	*(0.93)*	*(1.01)*	*(0.93)*	*(1.02)*	*(1.08)*
Initial school enrolment	0.0416**	0.0084	0.0082	0.0256	0.0161	0.0199
	(0.02)	*(0.02)*	*(0.02)*	*(0.02)*	*(0.02)*	*(0.02)*
Initial life expectancy	15.8522**	26.4482***	28.9747***	22.9938***	25.6656***	21.7974**
	(7.60)	*(8.64)*	*(9.11)*	*(8.50)*	*(8.97)*	*(9.11)*
Gross capital formation (% of GDP)	0.3997***	0.0642	0.0699	0.0341	0.0537	0.0294
	(0.03)	*(0.04)*	*(0.05)*	*(0.04)*	*(0.05)*	*(0.05)*
Taxes (% of GDP)	-0.1114***	-0.1064**	-0.0846	0.0145	-0.1023	-0.1112
	(0.04)	*(0.05)*	*(0.06)*	*(0.09)*	*(0.11)*	*(0.12)*
Political instability	1.9854	1.9950	2.5756	2.0956	2.9266	3.3740
	(2.37)	*(2.54)*	*(2.57)*	*(2.50)*	*(2.52)*	*(2.54)*
M2 (% of GDP)			-0.0187***		-0.0151***	-0.0147***
			(0.00)		*(0.00)*	*(0.00)*
Trade (% of GDP)			0.0217**		0.0224**	0.0182**
			(0.01)		*(0.01)*	*(0.01)*
Budget surplus (% of GDP)				0.0216	0.1196*	0.1010
				(0.06)	*(0.07)*	*(0.07)*
Education spending (% of GDP)	-0.0681	-0.2825**	-0.5195***	-0.2195*	-0.4056**	-1.1827***
	(0.10)	*(0.12)*	*(0.16)*	*(0.11)*	*(0.16)*	*(0.39)*
Other spending (% of GDP)				-0.1278**	-0.0251	-0.1775**
				(0.05)	*(0.06)*	*(0.06)*
Square term of education spending (% of GDP)						0.0844**
						(0.04)
Square term of other spending (% of GDP)						0.0017*
						(0.00)
Number of observations	1094	1078	903	1069	894	894

Notes: Standard errors in parentheses below parameters

***, **, * Statistical significance at 1%, 5% and 10% respectively

Table A9: Growth regressions with healthcare spending of high-income Sample 1 countries (1972-2012)

Estimation method	OLS	2SLS	2SLS	2SLS	2SLS	2SLS
Dependent variable	GR	GR	GR	GR	GR	GR
Endogenous variable		tax_gdp K	tax_gdp K	tax_gdp K	tax_gdp K	tax_gdp K
	(1)	**(2)**	**(3)**	**(4)**	**(5)**	**(6)**
Regressor	**b/se**	**b/se**	**b/se**	**b/se**	**b/se**	**b/se**
Initial GDP per capita	-7.5490***	-5.7314***	-5.9952***	-5.2610***	-5.6562***	-5.5071***
	(0.79)	*(0.89)*	*(1.00)*	*(0.90)*	*(1.02)*	*(1.05)*
Initial school enrolment	0.0355**	0.0041	0.0049	0.0190	0.0216	0.0280
	(0.02)	*(0.02)*	*(0.02)*	*(0.02)*	*(0.02)*	*(0.02)*
Initial life expectancy	13.5807*	26.0767***	29.5981***	24.5194***	26.7204***	24.8865***
	(7.43)	*(8.36)*	*(9.19)*	*(8.20)*	*(9.04)*	*(9.14)*
Gross capital formation (% of GDP)	0.3938***	0.0763*	0.0863*	0.0336	0.0503	0.0319
	(0.03)	*(0.04)*	*(0.05)*	*(0.04)*	*(0.05)*	*(0.05)*
Taxes (% of GDP)	-0.0566	-0.1016**	-0.0980*	0.0083	-0.0599	-0.1085
	(0.03)	*(0.05)*	*(0.06)*	*(0.09)*	*(0.11)*	*(0.11)*
Political instability	1.9198	1.9242	2.4021	2.2133	2.7809	3.2777
	(2.33)	*(2.46)*	*(2.57)*	*(2.41)*	*(2.52)*	*(2.54)*
M2 (% of GDP)			-0.0192***		-0.0152***	-0.0157***
			(0.00)		*(0.00)*	*(0.01)*
Trade (% of GDP)			0.0319***		0.0310***	0.0271***
			(0.01)		*(0.01)*	*(0.01)*
Budget surplus (% of GDP)				0.0617	0.1098	0.1230*
				(0.06)	*(0.07)*	*(0.07)*
Health spending (% of GDP)	-0.1372*	-0.1043	0.1051	-0.1113	0.1586	0.3071
	(0.08)	*(0.09)*	*(0.12)*	*(0.10)*	*(0.13)*	*(0.26)*
Other spending (% of GDP)				-0.1088**	-0.0620	-0.2293***
				(0.05)	*(0.06)*	*(0.06)*
Square term of health spending (% of GDP)						-0.0139
						(0.02)
Square term of other spending (% of GDP)						0.0021***
						(0.00)
Number of observations	1094	1077	903	1068	894	894

Notes: Standard errors in parentheses below parameters

***, **, * Statistical significance at 1%, 5% and 10% respectively

Table A10: Growth regressions with social welfare spending of high-income Sample 1 countries (1972-2012)

Estimation method	OLS	2SLS	2SLS	2SLS	2SLS	2SLS
Dependent variable	GR	GR	GR	GR	GR	GR
Endogenous variable		tax_gdp K	tax_gdp K	tax_gdp K	tax_gdp K	tax_gdp K
	(1)	**(2)**	**(3)**	**(4)**	**(5)**	**(6)**
Regressor	**b/se**	**b/se**	**b/se**	**b/se**	**b/se**	**b/se**
Initial GDP per capita	-7.7152***	-5.4616***	-5.2695***	-5.2553***	-5.3534***	-5.3540***
	(0.80)	*(0.93)*	*(1.03)*	*(0.94)*	*(1.04)*	*(1.06)*
Initial school enrolment	0.0466***	0.0169	0.0106	0.0257	0.0130	0.0137
	(0.02)	*(0.02)*	*(0.02)*	*(0.02)*	*(0.02)*	*(0.02)*
Initial life expectancy	13.8981*	32.0380***	35.1883***	28.8162***	32.4511***	33.4681***
	(7.58)	*(8.80)*	*(9.37)*	*(8.66)*	*(9.23)*	*(9.30)*
Gross capital formation (% of GDP)	0.3603***	-0.0687	-0.0726	-0.0647	-0.0547	-0.0555
	(0.03)	*(0.05)*	*(0.06)*	*(0.05)*	*(0.06)*	*(0.06)*
Taxes (% of GDP)	-0.0605*	-0.0383	-0.0156	0.0008	-0.0960	-0.0803
	(0.04)	*(0.05)*	*(0.06)*	*(0.09)*	*(0.11)*	*(0.11)*
Political instability	1.9776	2.3716	2.8629	2.2954	2.9887	2.8497
	(2.38)	*(2.58)*	*(2.61)*	*(2.53)*	*(2.56)*	*(2.57)*
M2 (% of GDP)			-0.0103**		-0.0091*	-0.0074
			(0.00)		*(0.00)*	*(0.01)*
Trade (% of GDP)			0.0208**		0.0229***	0.0251***
			(0.01)		*(0.01)*	*(0.01)*
Budget surplus (% of GDP)				0.0249	0.1004	0.1032
				(0.06)	*(0.07)*	*(0.07)*
Social welfare spending (% of GDP)	-0.1954***	-0.4780***	-0.5145***	-0.4634***	-0.4313***	-0.5475***
	(0.05)	*(0.06)*	*(0.07)*	*(0.07)*	*(0.09)*	*(0.20)*
Other spending (% of GDP)				-0.0608	0.0259	0.0802
				(0.05)	*(0.06)*	*(0.06)*
Square term of social welfare spending (% of GDP)						0.0042
						(0.01)
Square term of other spending (% of GDP)						-0.0008
						(0.00)
Number of observations	1095	1078	903	1069	894	894

Notes: Standard errors in parentheses below parameters

***, **, * Statistical significance at 1%, 5% and 10% respectively

Appendix 3: Choosing appropriate estimator for relationship between long-run GDP per capita and public spending

Using the pooled mean group (PMG) estimator, the long-run coefficients are constrained to be equal across countries. Blackburne and Frank (2007) claim that pooling across different panels, yields efficient and consistent estimates only when the restrictions are true. However, the hypothesis of slope homogeneity is often empirically rejected. In this case, the pooled mean group estimates become inconsistent. On the contrary, the mean group (MG) estimates, which permits long-run heterogeneity, are still consistent.

For this reason, the Hausman test is implemented to test the difference in these models. If the null hypothesis is not rejected, the PMG estimator is preferred to the MG estimator. Otherwise, the assumption of long-run homogeneity is violated. The following tables present the results of the Hausman test for developing Sample 3 countries and high-income OECD Sample 3 countries. We focus on the regression looking at the impact of an increase in total spending on long-run GDP level subsidised by different implicit financing elements.

3.1 Developing Sample 3 countries

The comparison between the pooled mean group and the mean group estimates is possible only in the case of budget deficit financing. The result has shown that the null hypothesis of long-run homogeneity cannot be rejected (see Table A11).

Table A11: The Hausman test for long-run homogeneity for developing Sample 3 countries (Study 3)

	Budget surplus	Dist. taxes	Non-dist. taxes	Dist/non-dist taxes
Chi-square	1.91	-30.13	-4.87	-4.75
p-value	0.86	-	-	-

Note: The null hypothesis is that PMG is preferred to MG estimates

3.2 High-income OECD Sample 3 countries

For high-income OECD Sample 3 countries, the pooled mean group estimates are preferred to the mean-group estimates regardless of the selection of implicit financing element (see Table A12).

Table A12: The Hausman test for long-run homogeneity for high-income OECD Sample 3 countries (Study 3)

	Budget surplus	**Dist. taxes**	**Non-dist. taxes**	**Dist/non-dist taxes**
Chi-square	6.73	3.31	6.66	3.36
p-value	0.24	0.65	0.25	0.50

Note: The null hypothesis is that PMG is preferred to MG estimates

As a result, the Hausman test suggests that pooled mean group estimate is preferred to mean group estimate. The assumption of long-run homogeneity is satisfied using data from our Sample 3 countries.

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